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Design, Operation and Performance of an Expendable Temperature and Velocity Profiler (XTVP)

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents system design and implementation information for the Expendable Temperature and Velocity Profiler (XTVP). The topics include discussions of the probe, acquisition equipment, analysis software, probe calibration, launch procedures, and error analysis.

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I. Introduction

The concept of measuring ocean currents from the motionally induced electric fields is an old one, having been first enunciated by Michael Faraday (1832). Numerous electric measurements have been made over submarine cables ~~(Longuet-Higgins, 1949)~~[a] and between electrodes towed behind a vessel ~~(von Arx, 1950)~~[b]. More recently a profiling instrument called the Electro Magnetic Velocity Profiler (EMVP) has been developed by Sanford, Drever and Dunlap (1978). Experience with the EMVP suggested that a smaller, expendable version could be developed. This report describes this development and performance results.

The development of the expendable profiler began in 1976 under support from ONR Code 481 (now 422). A device was needed to sense voltages between two electrodes, effectively spaced 5 cm apart, to within 50 x 10^{-9} V rms over a 1 Hz bandwidth. The sensitivity results from the necessity to measure the expected signal to the equivalent of about 1 cm/s rms. To be operable from a ship under way, the device must not only be expendable but also able to transmit data to the vessel. For reasons of cost and convenience, body parts and wire spools from a T-7 XBT (Expendable Bathy-Thermograph, Sippican Corp., Marion, MA) were utilized, providing a suitable vehicle and the means for transmitting the data back to the vessel over the wire link.

Development activity proceeded into 1977 with the design of several electronics circuits and the performance of sea trials. The results were not encouraging; a persistent electronic instability arose within each probe.

During 1977, Code 500 of the Naval Oceanographic Research and Development Activity (NORDA) at Bay St. Louis, MS, took over program support. After the unsuccessful sea trials in 1977, efforts were concentrated on laboratory testing and theoretical evaluations to discover the cause of the electronic instability. Ultimately this problem was found to be due to feedback from the turns on the probe wire spool into the low-level electrode amplifiers.

By spring 1978, the instability had been isolated and new circuits designed to eliminate the problem. About two dozen probes were taken to sea on Oceanus Cruise 42 in April 1978. These probes were successful and revealed stable profile-to-profile repeatability.

In June 1978, a complement of over 50 probes was taken on Cruise 47 of the R.V. Oceanus as part of the Local Dynamics Experiment of the U.S./U.S.S.R. POLYMODE program. These probes, which we call XTVP's for Expendable Temperature and Velocity Profiler, were used simultaneously with our recoverable profiler (the Absolute Velocity Profiler, successor to the EMVP) and alone to study upper-ocean velocity features such as internal waves and fronts.

With the support of the Applied Physics Laboratory of the Johns Hopkins University, a series of performance tests was conducted in May 1978 at the U.S. Navy's AUTEC (Atlantic Underwater Test and Evaluation Center). A free-fall, acoustically tracked profiler was operated by Wenstrand (1979) as the standard against which the XTVP's were compared. These tests, reported by Sanford, Dunlap and Drever (1981), showed that the probes were accurate to within about 1 cm/s rms. The XTVP's do not measure the vertically averaged flow but reveal only the depth dependent part. Hence, the two profilers can only be compared with an unknown velocity offset. The 1 cm/s rms performance reflects the expected differences when the XTVP profile has been offset to match the acoustic profile's vertical average.

At the AUTEC trials, XTVP's manufactured by the Sippican Corporation according to a slightly different design were also tested. These did not perform quite as well as those built by APL-UW, and the changes incorporated were not included in subsequent units.

Several hundreds of Sippican-produced probes were deployed in experiments in the fall and winter of 1979-80. These probes performed well, with a failure rate of about 1 in 4.

During 1979, a new digital receiver was designed and built. This device determines the amplitudes and phases of the electric field and compass signals, from which the velocity estimates result. These quantities are derived from direct frequency evaluation of the FM signals, eliminating the analog stages (frequency to voltage and analog synchronous demodulation) of the original profile processor. The digital receiver was interfaced to an HP 9845T desk-top computer. Raw data were acquired in real time, but a processed profile requires too much computation to be produced in real time.

The recent emphasis of the program has been on our using the probes, assisting others in probe deployment and processing, and completion of a digital receiver, especially a means for internal digital storage.

To many readers it may seem unconscionable to expend such sophisticated probes. But when used to this maximum advantage, these devices provide invaluable results and save considerable personnel and operational costs. Operation of an equivalent recoverable instrument is very expensive in terms of capital equipment (support equipment, the profiler, spares, etc.), highly trained personnel (engineers, technicians, programmers) and ship time for launch, search and recovery. Clearly, there is some point at which the scientific and operational requirements argue strongly for the advantages of operational speed, real-time data presentation, logistical convenience and routine operation by minimally trained personnel.

II. Principles of Motional Induction

As seawater moves through the earth's magnetic field, electric fields, currents and magnetic fields arise. The physics is identical to that demonstrated as a wire connected to a voltmeter is moved between the poles of a magnet. The voltmeter registers an emf as the wire enters and exits the pole area. A similar experiment can be performed with the wire loop just in the presence of the geomagnetic field. If the loop were to change its area or be rotated, an emf would be induced. Note that the loop area projected onto the geomagnetic field must change. Motion of the loop and voltmeter in any rectilinear direction will not result in an induced emf. There seems to be a contradiction here in that we assert that velocity can be detected by the XTVP, but not in the above example. The resolution is that in the rigidly translating loop and voltmeter all circuit elements move together with no relative velocity. If the loop were elastic with a section moving away from the voltmeter, then an emf would arise proportional to the rate of change of magnetic flux through the loop area. If the voltmeter were also moving, then the emf may be proportional to the velocity of the loop section minus (or relative to) that of the voltmeter. The general point is that the emf is related to the motion of all circuit or loop elements. The same principle applies to the ocean; namely, the emf induced by the velocity at some depth will be relative to the velocities in the surrounding seawater. It is this fact that restricts the XTVP velocity measurements to be relative to an unknown, spatially averaged velocity. This restriction is indeed unfortunate, but there is one important consolation: the unknown is not depth dependent, so it represents only an offset having no vertical structure. In most, if not all, geophysical flows, the vertical scale of the motion is small compared with the horizontal length scale. This low aspect ratio leads to the assertion that the offset is not depth dependent. A more rigorous analysis of motional induction is presented by Sanford (1971), and Sanford et al. (1978) discuss induction using a discrete circuit analog.

In addition to the obvious problem of nanovolt measurement in the severe pressure and temperature environment of a profile, there are other special considerations. The fall rate of 4-5 m/s (8-10 knots) means that there will be an extremely large signal generated by this motion through the horizontal magnetic field. This voltage will be about 5 μV. The extraction of voltage due to horizontal velocities (~50 nV) in the presence of a 40 dB larger one is difficult. A scheme is employed using the compass coil to cancel the bulk of the fall induced voltage. Another consideration is that electrodes have enormous (>1 mV) drifts and offsets and have broadband noise. To extract 50 nV signals, it is necessary to limit the bandwidth of the desired signal. This is achieved with a rapid probe rotation rate, which modulates the

ocean's emf and allows the separation of the induced signal from broadband noise and the lower frequency drift of the electrodes. Finally, the transmission of the data to the vessel must be carefully executed to avoid feedback from the high-level output into the low-level input.

III. Method of Operation of the Expendable Profiler

The method of operation of the expendable temperature and velocity profiler has been developed based on our experience with a free-fall electromagnetic velocity profiler (EMVP; Sanford et al., 1978). The XTVP shown in Fig. 1 is made from standard expendable bathythermograph (XBT, Sippican Corp.) parts with the addition of a 29.5 cm center section of active electronics. As the probe falls and spins through the water column, it modulates the motionally induced electric field at its spin frequency. These weak signals are amplified and converted to an FM signal that is transmitted over a pair of #39 wires to the ship.

The signal $\Delta\phi$ from a falling, rotating electrode line pointing in the direction θ, measured clockwise from geomagnetic north, in the presence of the motionally induced electric currents in the sea is

$$\Delta\phi = F_z L(u-\bar{u})(1+C_1)\cos\theta - [F_z L(v-\bar{v})(1+C_1) - F_H LW(1+C_2)]\sin\theta, \quad (1)$$

where

F_H and F_z	=	horizontal and vertical components of the geomagnetic field, taken here as 1/4 and $-1/2 \times 10^{-4}$ tesla,
L	=	length of electrode line = 5×10^{-2} m,
$u-\bar{u}$ and $v-\bar{v}$	=	east and north horizontal velocity components minus a vertically-averaged contribution,
C_1 and C_2	=	scale factors depending on the shape of the probe ≈ 1 and 0,
W	=	vertical component of velocity (negative value for falling probe) ≈ 4 m/s.

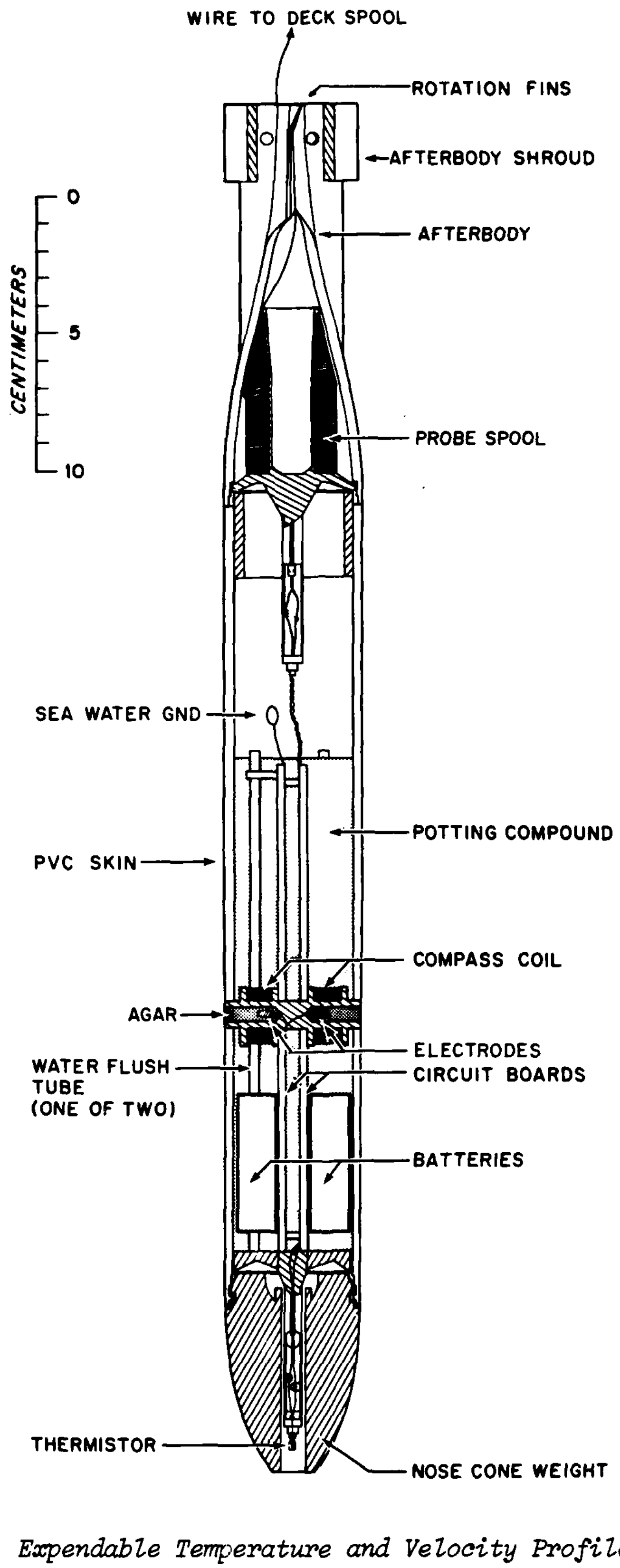

Figure 1. Expendable Temperature and Velocity Profiler (XTVP)

The magnitudes of the terms are found for $u-\bar{u}$ and $v-\bar{v}$ = 1 cm/s using

$$F_z L(u-\bar{u})(1+C_1) = F_z L(v-\bar{v})(1+C_1) = -50 \times 10^{-9} \text{ V} , \tag{2}$$

and

$$F_H LW(1+C_2) = 5 \times 10^{-6} \text{ V} . \tag{3}$$

The very low signal levels place stringent requirements on the expendable electronics. The desired signal of 0.05 μV represents 1.0% of the 5 μV signal induced by fall speed. To resolve the desired signal to an uncertainty of 1 cm/s requires that the gain of the amplifiers be stable within 1.0%, that the phase of the signal relative to the electrode line orientation be determined to 0.6°, and that the fall speed be known to about 1.0%.

The 0.6° is a specification that is very hard to meet in an expendable probe. The phase error tolerance can be improved by mixing a portion of the coil signal with the electric field. The amplitude of the coil signal is given by $F_H \omega nA$, where ω is the rotation rate and nA is the effective area times the number of turns. Consequently, the electric field signal plus the coil contribution would be

$$\text{in-phase} = -F_z L(v-\bar{v})(1+C_1) = F_H LW(1+C_2) - F_H \omega nAC_3 , \tag{4}$$

where C_3 is the fraction of the coil signal added. The value of C_3 is chosen such that for average fall rates and rotation frequencies (W and ω) the two terms nearly cancel. That is, we find that $\omega = 50 \text{ s}^{-1}$ and $nA = 10^3 \text{ cm}^2$, hence

$$C_3 = \frac{L\bar{W}(1+C_2)}{\bar{\omega} nA} \sim \frac{1}{25} . \tag{5}$$

The principal benefit of this procedure is to reduce by about 90% the magnitude of the in-phase signal, making the in-phase and quadrature signals of comparable strength. In this case, phase shift uncertainties in the probe and deck equipment can be as large as ±6° without degrading the ±1 cm/s performance goal.

The low-noise preamplifiers used in the probes have a noise voltage of about 10×10^{-9} V/$\sqrt{\text{Hz}}$ in the 5 Hz to 1000 Hz band referred to input. This noise level corresponds to an ~1/4 cm/s rms uncertainty in velocity.

The discussion of the hardware is divided into topics related to the probe construction and electronics and the receivers, both analog and digital versions.

A. PROBE

1. Package and Construction

The mechanical design of the probe is shown in Fig. 1. The probe is 52 cm long, 5 cm in diameter, and weighs in air approximately 1470 grams. In seawater the probe weighs about 800 grams. The three main parts of the probe are the afterbody, electronics section and nose weight.

The afterbody contains a spool of approximately 900 m of two-conductor, #39 wire used to send data to the surface. A shroud in the form of a right cylindrical shell has been mounted on the afterbody to stabilize the fall of the probe. The fins of the afterbody make the probe rotate at about 450 rpm.

The electronics section contains two printed-circuit boards, batteries, electrodes, compass coil and thermistor flushing tubes, all potted inside a thin-walled PVC tube. The potting is a soft compound which allows the components to be at pressure equilibrium with the surrounding seawater. The electric field sensor is made up of two silver-silver chloride electrodes in tubes filled with agar to form a salt bridge for making electrical connection to the seawater at the outer skin of the probe. The compass coil is a coil of wire wound coaxially over the electrode tubes.

The nose weight is made of zinc, weighs about 500 grams in seawater and supplies the main driving force causing the probe to fall. A thermistor is mounted in the hole in the center of the nose weight. The thermistor is flushed by water passing through the nose cone and then through the flushing tubes which are potted in the electronics section.

2. Electronics

The electronics are made up of sensor preamplifiers, three voltage-to-frequency converters (V/F), a battery pack, voltage reference, mixer and line driver. Figure 2 is a block diagram of the probe electronics.

The electric field, as sensed by the electrodes, is amplified by a low noise preamplifier. The signal generated by the rotation of the compass coil in the earth's magnetic field is also amplified. The compass coil and the electrodes have been wired so that the output of the compass amplifier will be 180° out of phase with the part of the electric field amplifier output that is due to the fall rate term, $F_H LW(1+C_2)$, of Eq. (1). As described in Eq. (4), a small amount of the compass coil amplifier signal is added to the electric field amplifier signal to cancel most of the fall rate term. The output of the electric field post-amplifier is ac coupled into a V/F converter. The reference voltage is used to offset the V/F to operate at the center frequency of its designated channel. The output of the V/F is divided by two to eliminate the even harmonics. The signal is then filtered to reduce the third harmonic and to give a 10 dB boost to the higher-frequency portion of the channel over the lower-frequency end. The compass signal is also ac coupled into a V/F, and the output of the V/F is divided by two to remove the even harmonics.

The thermistor is used with the reference voltage to modulate a third V/F. The output of the temperature V/F is divided by two to remove the even harmonics. The signal is then filtered to reduce the odd harmonics.

The three FM channels are amplified to compensate for the different signal attenuation on each channel (caused by the wire link to the shipboard processing system), mixed and impressed on the wire link. Design signal levels and the actual signal levels out of a wire link for a couple of drops are shown in Fig. 3. There are curves showing the signal levels at the start and end of a drop. The attenuation of signal on the wire can be as much as 120 dB at 5 kHz with all the wire in the water. Figure 4 shows the frequency spectra of signals out of the digital receiver preamplifier at three different times for drop #67. The broadband energy centered at 2500 Hz in the top spectrum is caused by the electric field amplifier in the probe being open-circuited while in air in the deck launcher. The figure shows that even when the signals are greatly affected by the wire links they still stand out well above the noise.

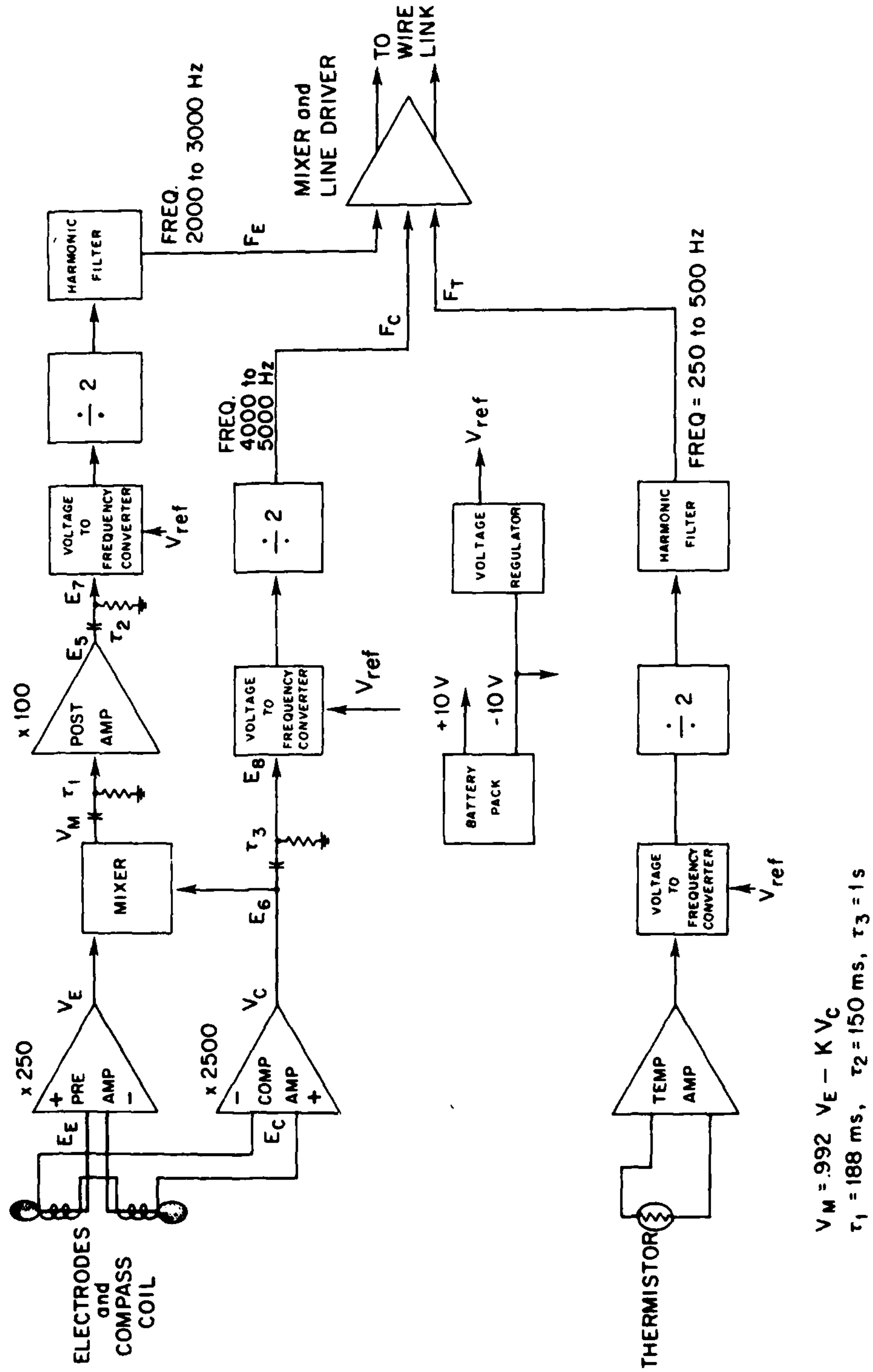

Figure 2. Diagram of probe electronics.

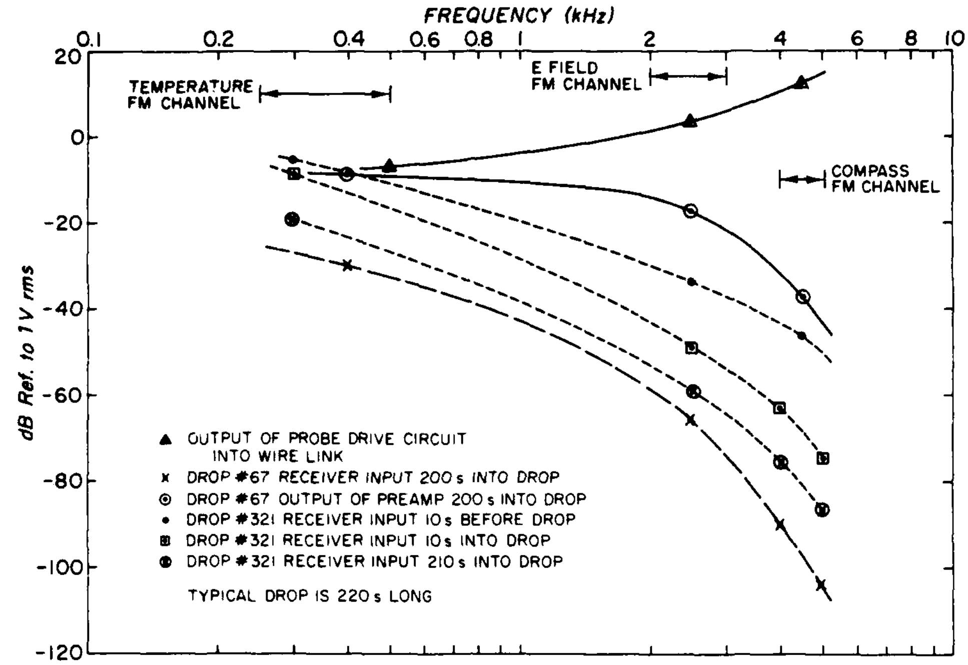

Figure 3. Typical signal spectra at probe, receiver input and after preamplifier at various times into a drop.

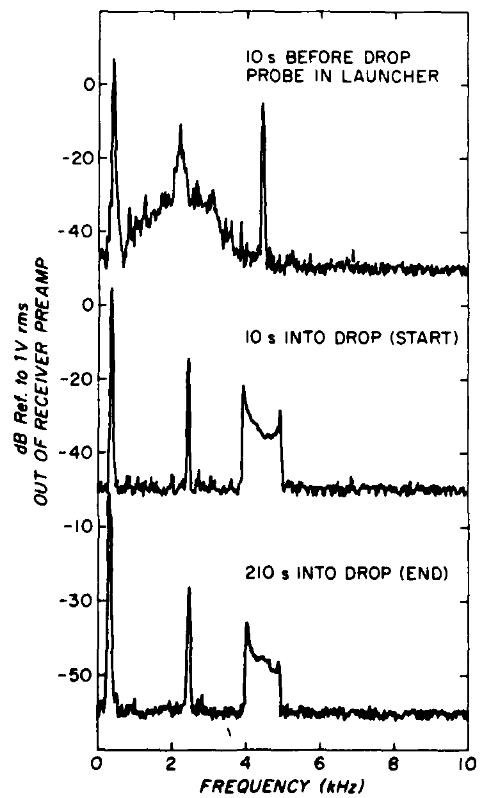

Figure 4.

Signal spectra 10 seconds before and after probe launch, and near the end of a drop.

B. ANALOG RECEIVING SYSTEM

The analog receiving system, Fig. 5, consists of the XTVP receiver, two custom-designed plug-in units for a Tektronix TM 500 module, and standard laboratory instrumentation.

The three channels of FM data are transmitted to the ship by way of the expendable wire link. The signals are transformer coupled, amplified and filtered into the three separate frequency bands. These three FM signals are recorded on an HP 3960 tape recorder so the data can be replayed after the drop. The period of the temperature frequency is measured in a counter and converted to a voltage V_T which can be displayed on the XY plotter. The electric field and compass frequencies are converted to voltages, V_E and V_C, respectively, that are a linear representation of the voltages sensed by the probe.

The compass voltage V_C is used as a reference signal for the two-phase, lock-in amplifier (PAR, Inc., Model 129). The lock-in amplifier synchronously demodulates the electric field voltage into in-phase (north-south) and quadrature (east-west) components with respect to the compass signal. These signals are recorded in the two-pen XYY recorder as a function of time (depth) in real time as the probe is falling. Thus, the velocity data are available for immediate examination and analysis in analog form.

The processing system also measures and plots the in-phase and quadrature components of the compass signal and the period of the compass signal.

The velocity profiles produced by the analog system contain errors and lack corrections for known systematic effects. To compute corrected profiles, it is necessary to digitize the analog plots. To accomplish this we have used an HP 9874A digitizer and an HP 9845 desk-top computer. The analog receiver has now been replaced by a digital version; the analog receiver now serves as a backup to the digital receiver and provides real-time information.

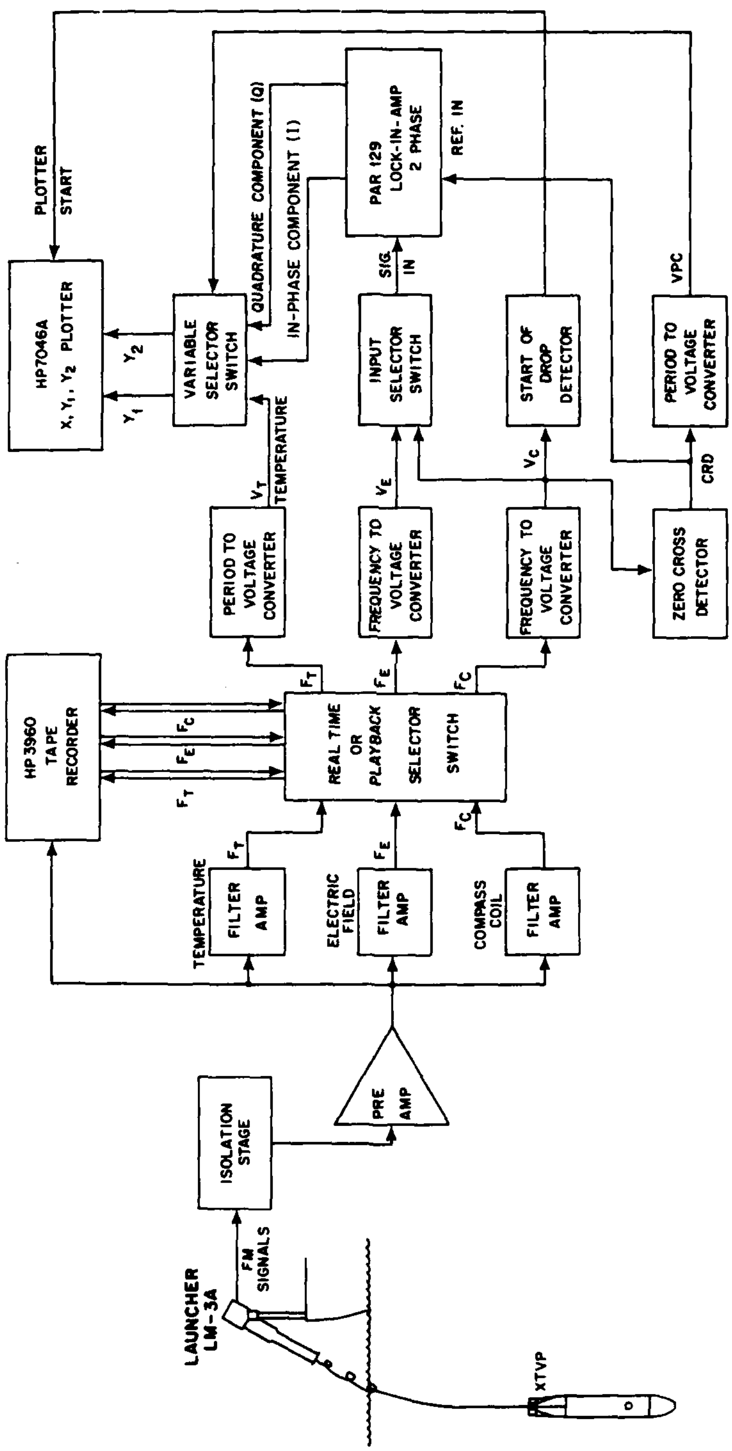

Figure 5. Analog or digital-backup XTVP shipboard processing system.

C. DIGITAL RECEIVER

The XTVP digital receiver is a one-box unit that takes the composite FM signals from the wire link and processes them into digital data that are recorded on an internal magnetic cartridge tape recorder. In this way, the receiver is capable of being used without an on-line computer. With an X,Y_1,Y_2 plotter, as shown in Fig. 6, the receiver can be used to obtain real-time plots of u and v with X equal to the product of time and a constant fall rate similar to those produced by the analog receiver. It is recommended that a backup magnetic tape recording be made of the FM signals. The data must be further processed by a computer to get completely processed profiles.

1. Preamplifier, Filters and Carrier Detector

The preamplifier and filters take the signal from the output of the wire link, amplify, and separate the FM signal into the three channels. The signals from the wire link are coupled into the launcher and fed to the input of the receiver by a shielded, four-wire cable. At the input to the receiver, the signal is passed through an isolation transformer followed by the preamp which has frequency-dependent gain. The compass channel has a gain of approximately 40 dB. The electric field channel is boosted approximately 25 dB, and the temperature channel has a gain of approximately 10 dB. The effect of the nonuniform gain appears in Fig. 4 as the difference between the two curves showing drop #67 signal levels into the receiver and out of the preamp. The signal then goes through three bandpass filters that separate and further amplify the signals. The outputs of the filters are recorded on a magnetic tape recorder and applied to the inputs of the carrier detectors. When the carrier voltage of each channel goes above a preset value, the FM signal will be gated into the phase lock loops. The carrier detector circuit serves to keep the phase lock loop squelched until a carrier is present. The carrier detector generates 3 bits of the status data word which is used by the processing computer to determine that all carriers are present during the drop.

2. Phase Lock Loops

The phase lock loops perform the three functions of frequency multiplication, frequency-to-voltage conversion and signal-to-noise improvement at low carrier levels.

The most important function of the phase lock loops (PLL) is to multiply the carrier frequency such that a zero crossing counter will have sufficient resolution for making the velocity determinations. The electric field carrier frequency has a transfer function from the input of the electrodes of the probe to the PLL input of 2.5 Hz per 0.1 μV peak to peak. An ocean flow having a horizontal speed of 1 cm/s in a

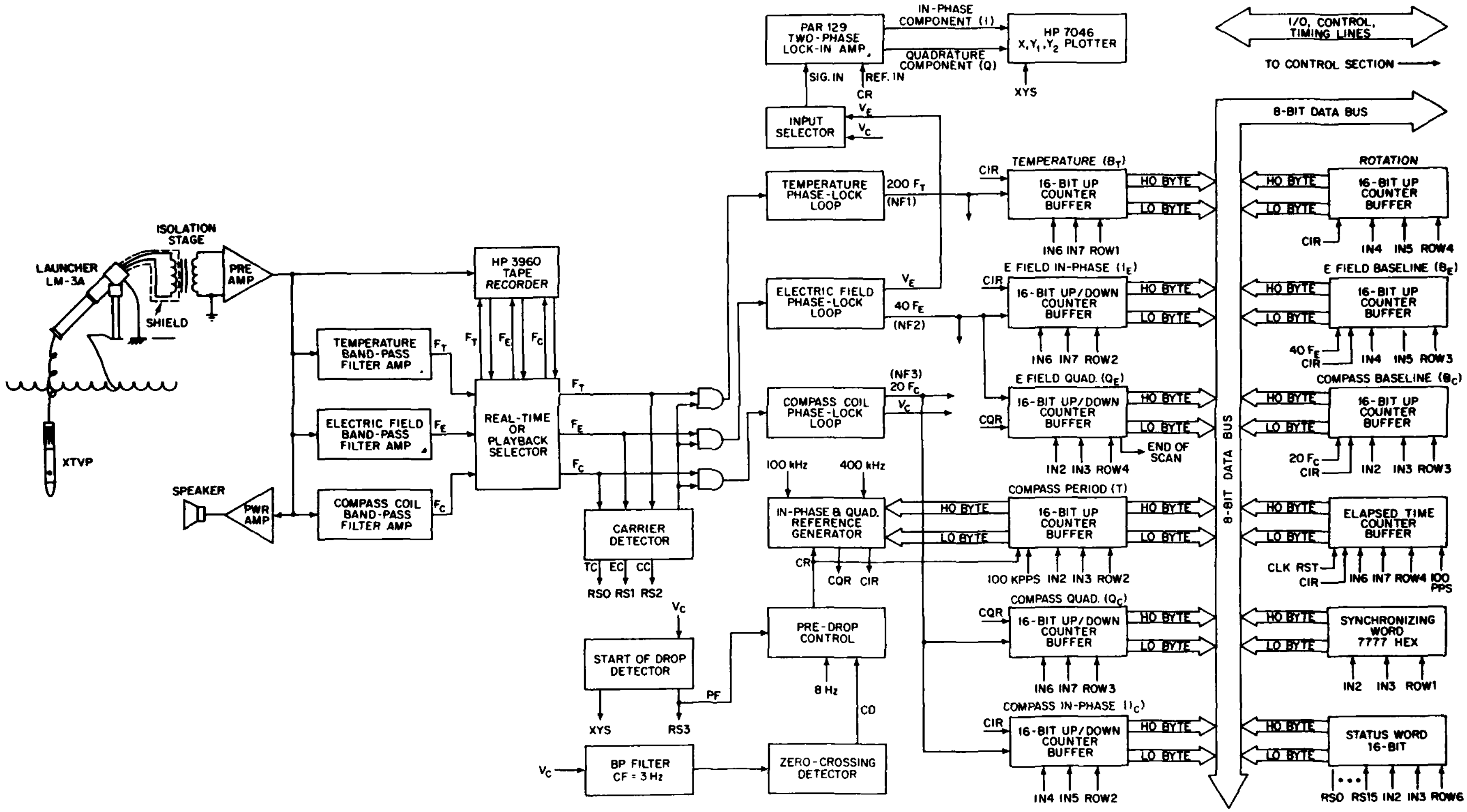

Figure 6. Processing section of XTVP digital receiver (control and I/O sections shown in Fig. 8).

vertical geomagnetic field of $1/2 \times 10^{-4}$ tesla will induce a signal of 0.1 μV peak to peak at the probe electrodes. The electric field carrier frequency is multiplied by 40, increasing the transfer function to 100 Hz per 0.1 μV peak to peak. The counters are used in an up/down count mode over one period of probe rotation. Because the up/down counter accumulates over one period, and the modulation of the carrier is a sine wave at the period of rotation, it can be shown that

$$TC = \frac{2F_p N}{\pi} P , \tag{6}$$

where

TC = total counts in up/down counter,
F_p = deviation of carrier frequency per μV,
P = period of rotation in seconds,
N = multiplication factor of PLL.

For $P = 0.125$ s, $F_p = 25$ Hz/μV and $N = 40$, $TC = 125$ counts/μV ≈ 12.5 counts/cm/s.

The second function that the PLL's perform is frequency-to-voltage (analog) conversion of the electric field and compass FM signals. The compass analog voltage signal is used by the reference generator to produce reference signals for the phase-sensitive demodulation of the FM signals. The electric field and compass analog signals can also be used with a two-phase lock-in amplifier as was done in the original analog receiver described previously.

A third function of the PLL is to achieve an improvement in signal-to-noise ratio at small carrier-to-noise ratios. The output signal-to-noise ratio of an FM signal is (Schwartz, 1966)

$$\frac{S_o}{N_o} = 3\beta^2 \frac{S_c}{N_c} , \tag{7}$$

where

$\frac{S_c}{N_c}$ ≡ FM carrier-to-noise ratio (must be greater than 10),
$\beta \equiv \frac{\Delta f}{f_m}$ = modulation index,
f_m ≡ frequency of the modulation in radians/s,
Δf ≡ deviation of the carrier frequency from zero modulation frequency of the carrier.

For $\Delta f = 500$ Hz, $f_m = 8$ Hz and $S_c/N_c = 10$, $S_o N_o = 39{,}000$ or 46 dB.

Below the $S_c/N_c = 10$ threshold, Eq. (7) is not valid, and S_o/N_o declines about 30 dB by the point where $S_c/N_c = 1$. Schwartz (1966) shows that a PLL can be used to move the threshold down to about 0 dB giving a threshold improvement of 10 dB.

3. Reference Generator and Up/Down Counter

The reference generator and the up/down counters perform the function of phase-sensitive demodulation of the FM signals into two orthogonal components. The reference generator generates two reference signals, CQR and CIR, with the former lagging the latter by 90°. These signals are used to control the up and down counting times of the up/down counters. Figure 7 shows the important signals that are used to generate the reference signals for controlling the up/down counters. V_C is the ac coupled demodulated analog signal out of the compass PLL. The signal CR is generated by detecting the zero crossings of V_C. The period of CR is measured by a digital counter for every rotation of the probe with a resolution of 10 μs. The period measurement is stored on the tape recorder and in a temporary buffer. The data in this temporary buffer are used to preset a down counter which counts at a rate four times faster than the period up counter. This down count is repeated to generate the signal *S1*, which is a series of pulses that roughly divides the time period into four equal parts. The S1 signal is used to generate the S2 signal. S2 is generated by a one-stage flip-flop that is reset at t_0 and t_4 and stepped at t_1, t_2 and t_3. The positive-going edge of S2 is used to clock the state of CR into a 1 bit data register. The output of the data register is the Compass Quadrature Reference signal (CQR). The Compass In-Phase Reference (CIR) is generated by clocking a one into a data register at t_0 to t_4 and a zero in at t_2. There are small errors in the generation of CQR and CIR, which are corrected when the data are processed in the computer. CIR is used rather than CR because if there is any baseline wandering of V_C it will appear as noise in the timing of the negative-going edge of CR. But since the time of the negative-going edge of CR is not measured, a correction cannot be implemented.

The four up/down counters shown in Fig. 6 are controlled by CQR and CIR. These counters up/down count the PLL frequencies, NF_2 and NF_3. At the end of a count period, the counters have measured the in-phase and quadrature components of the electric field and compass signals. The two components of the compass signal are used to correct for the phase shift error caused by the receiver between CQR and the FM modulated signal from which V_C is derived. The compass components are also used to eliminate the fall velocity component. The up/down counters average

the baseline carrier frequencies of the FM signals. These are counters that just count up, making a measurement of the baseline carrier frequencies of electric field, compass coil and temperature signals. There is also a counter that measures elapsed time to the nearest 10 ms.

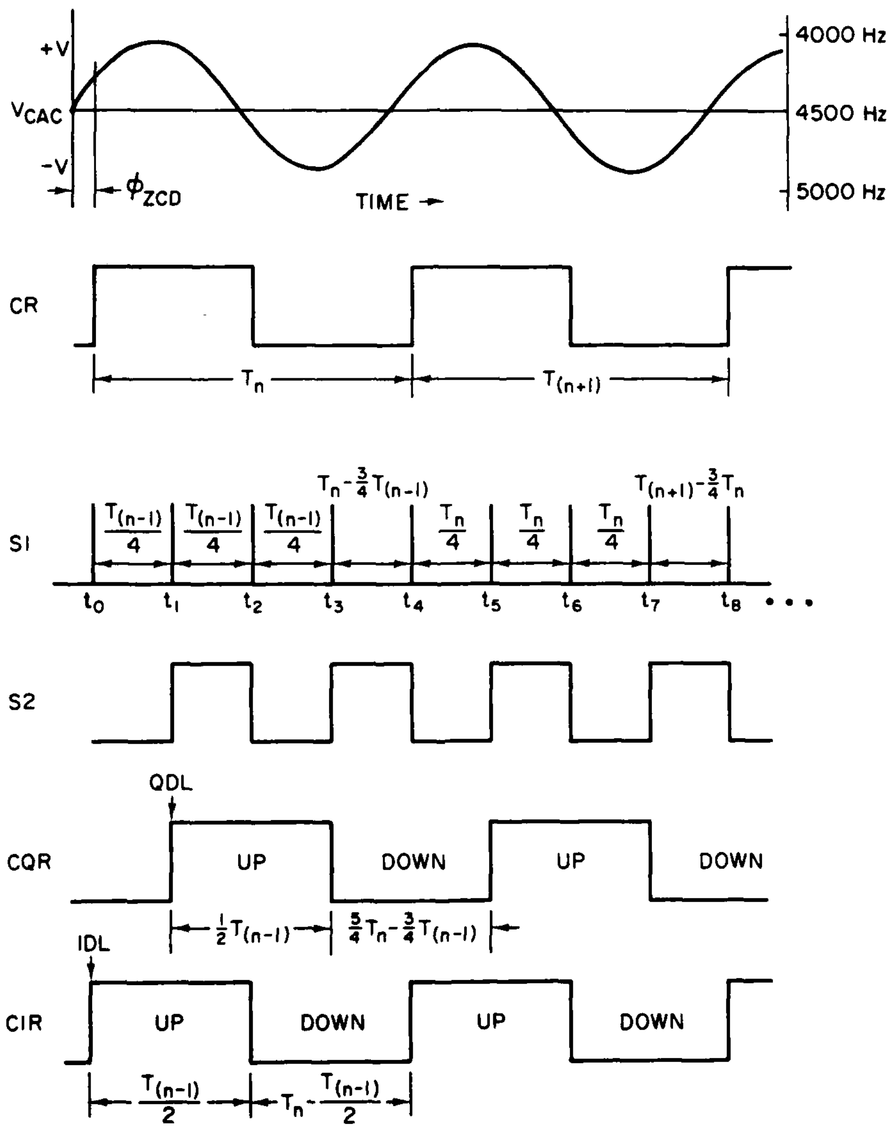

Figure 7. Timing diagram for in-phase and quad-phase counters.

4. Pre-Drop and Start of Drop Controls

The start of a drop is detected by sensing when the compass analog signal V_C goes above a preset threshold. Going above the threshold sets a flag called PF (probe falling) and, as long as the threshold is reached at least once every 600 ms, the flag will stay true.

The threshold is set so that when a probe starts falling and rotating the PF flag will turn on within 1 s. The threshold setting is dependent on the earth's horizontal magnetic field. The threshold can be increased near the magnetic equator to reduce false triggers. At high latitudes the threshold must be reduced. Note that when the horizontal magnetic field is nearly zero the system cannot develop an accurate CD signal and thus velocity information is compromised.

The PF flag is used by the receiver to switch CR between an 8-Hz square wave generated by the time base and CD. V_C is used to generate CD by passing it through the zero-crossing detector. The 8 Hz square wave is used as a default signal by the receiver to collect data before and after a drop. Without it there would be no timing signals for the counters.

5. Controller

The controller shown in Fig. 8 regulates the collection and processing of digital data in the receiver. The heart of the controller is an RCA 1802 microprocessor with 6K (K=1024) bytes (8 bits) of EPROM (erasable, programmable read-only memory) and 16K bytes of RAM (read and write memory). Data are collected by the controller, stored on internal magnetic tape and sent to the HP 9845 computer. The flow of data is controlled by a seven-level priority code for interrupts and DMA (direct memory access) transfers.

The receiver's operator enters data and commands through a 16-pad numeric keyboard, a 20-digit alphanumeric display and control switches on the front panel. The operator is able to enter into the receiver the data to be recorded on the magnetic tape along with the profile data collected during an actual drop. The data recorded and the storage format will be discussed later in the tape recorder section.

The controller also has the capability of performing a small amount of data processing to provide a quick look at the profiles in real time on an external XYY plotter. The counter values from a single rotation are normalized by the rotation period and averaged over a number of rotations. These processed data are sent to the three, digital to analog converters.

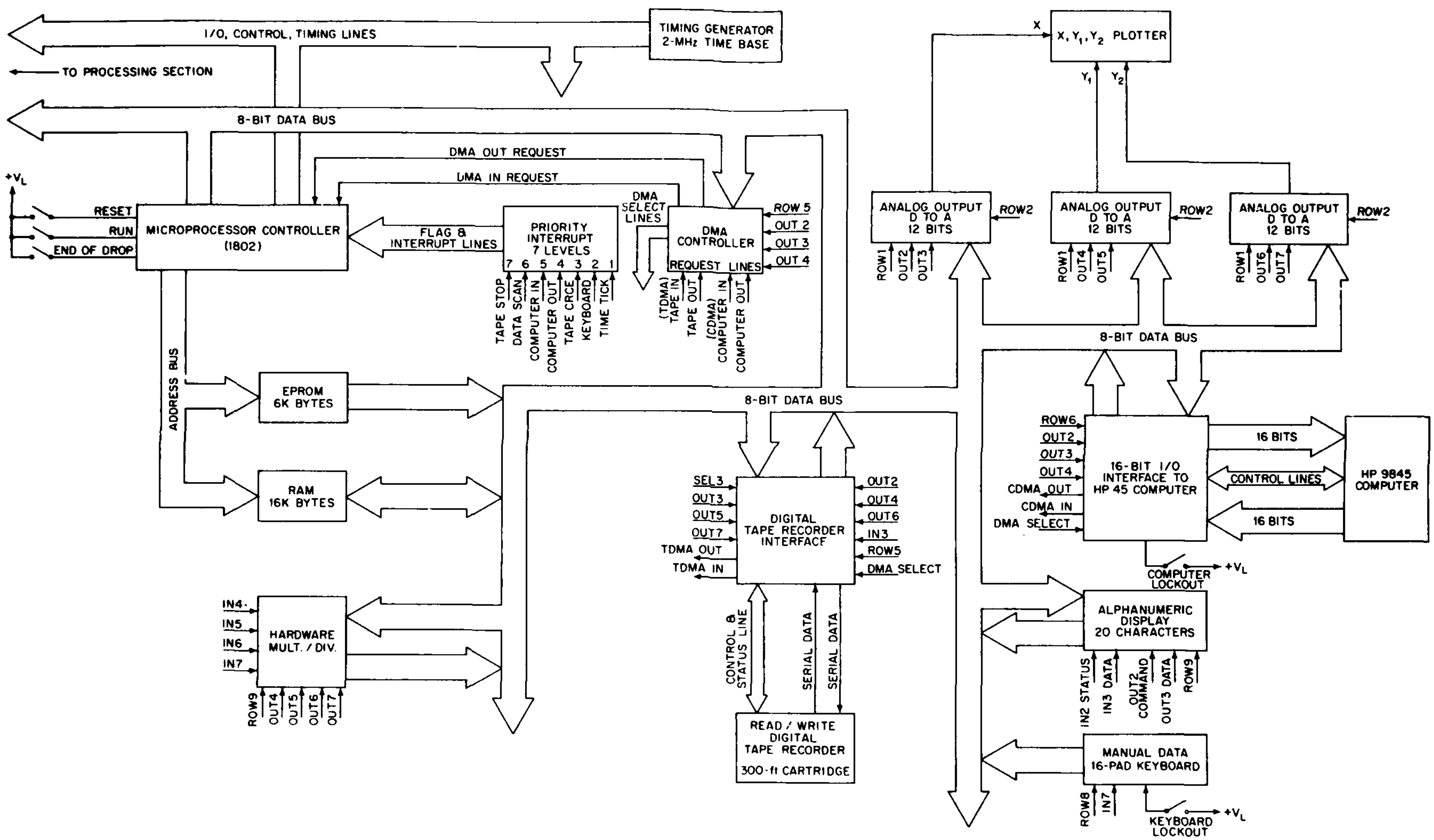

Figure 8. Control and I/O sections of XTVP digital receiver.

Data from the signal processing section buffers are collected once every rotation of the probe and stored in RAM until a 2K byte buffer is filled. The controller then sends the 2K data buffer to the tape recorder and HP 9845. Besides storing data, the controller can also find the digital data for a particular drop on the digital tape recorder and play it back for quick-look processing or pass it on to the HP 9845.

6. Digital Tape Recorder

The tape recorder is Digital Electronic's Model 3447 cartridge magnetic tape drive with four tracks and erase, write and read heads. We use 3M DC300A 1/4-inch tape cartridges with a storage capacity of approximately 10 million bytes of unformatted data. Data are recorded serially at 6400 bits per inch.

The data capacity is much greater than is needed by the receiver, but it was cost effective to use a design shared with another program. One cartridge can store more than 50 drops, but because of the high probe cost relative to tape cost it is recommended that not more than 10 drops be put on a cartridge.

The tape drive reads immediately after writing and performs a CRC (cycle redundancy check) on the data read. In the event of an error, the data block is recorded again (without backspacing and erasing the first). The controller will try three times to write the data block, and then move on to record the next block of data.

Data are recorded in 2K-byte-long records. There are only three types of records: data records, end-of-file records and end-of-information records. The end-of-information record indicates where recording can begin without writing over previous data; it is always added to the tape at the completion of a drop. Because the amount of data storage is not a problem, all records have 128 byte headers. The header is made up of words that are 2 bytes each (16 bits). Table 1 is a list of the words and their position in the header.

The preamble is used by the tape recorder electronics to find a record during a tape read. When the recorder is searching for data, it looks for at least 39 zeros followed by a one before it will put its DAD (data detected) line true.

The controller will write an end-of-file record and an end-of-information (EOI) record at the end of each drop when the operator sets the end-of-drop switch on the front panel. When a new drop is to be recorded on tape, the controller looks for the EOI record and positions the tape write head in the inter-record gap before the EOI record. At the start of writing the new drop, the EOI record will be erased.

Table 1.

Word #	Name	Data (HEX)
1	Preamble	0000
2	Preamble	0000
3	Preamble	0001
4	Keyword (record type)	
	Data record	AAAA
	End-of-file record	AAAB
	End-of-information record	AAAC
5	Record #	
6	Number of times the record has been recorded on tape	
7	Version # of receiver program	
8	Number of data words per scan	
9	Tape # (cartridge #)	
10	Track #	
11	Cruise #	
12	Drop #	
13	Version # of drop	
14	Number of files on tape, including this drop	
15	Real time year	
16	Real time day of year	
17	Real time hours (24)	
18	Real time minutes	
19	Real time seconds	
20	Number of previous scans in this file	
21	Number of previous scans in this record	
22-64	These are spares that are filled with all F's.	

Each record has one record header and 64 scans of data. One scan of data contains all the data collected during one rotation of the probe. The makeup of the scan is given in Table 2.

Table 2.

Channel #	Name	No. of Bytes
1	Sync. word (7777HEX)	2
2	Status	2
	Bit # (true state = 1)	
	0 temperature carrier present	
	1 E field carrier present	
	2 Compass carrier present	
	3 Probe falling (PF)	
	4 Compass channel F3	
	5 8 Hz default OFF	
	6 Manual XY start	
	7 Real time mode	
	8 CTLO (HP 9845 control line 0)	
	9 CTLI (HP 9845 control line 1)	
	10 Spare	
	11 Spare	
	12 Spare	
	13 Spare	
	14 Spare	
	15 End of drop	
3	Temperature baseline (B_T)	2
4	Period of rotation (T)	2
5	Compass in-phase (I_C)	2
6	E field in-phase (I_E)	2
7	Compass baseline (B_C)	2
8	E field baseline (B_E)	2
9	Compass quadrature (Q_C)	2
10	E field quadrature (Q_E)	2
11	Rotation counter	2
12	Elapsed time counter	2
13	Real time hours (24/day)	2
14	Real time minutes	2
15	Real time seconds	2
	Total	30

For a rotation rate of 8 Hz, it takes about 8 seconds to fill the 2K byte buffer of data.

7. Computer Interface

The HP 9845T computer is connected to the receiver by a 16 bit parallel I/O interface. The computer can send control words to the receiver to initialize a transfer of data. The receiver is designed to allow the HP 9845 to read and write anywhere in the RAM memory space of the receiver. The HP 9845 can also read from the EPROM memory space to check the EPROM in case of a problem that is caused by the receiver program. Data are transferred through the interface by DMA. The maximum rate of data transfer is limited by the receiver to about 64K bytes per second, not including the transfer setup time of the 9845. It takes about 32 ms plus setup time to transfer a 2K byte block of data.

During a probe drop, the 9845 can be locked out from writing into the memory of the receiver. With the computer lock-out switch on, only the data blocks will be transmitted to the 9845.

8. Analog and FM Outputs

The receiver has analog and FM outputs that are used for a quick look and for backup data storage. There are two means for getting a quick look at the analog profile. The analog voltages of electric field and compass coil are available on BNC connectors on the front panel. These signals can be fed into a two-phase lock-in amplifier that will demodulate the electric field into two components using the compass coil voltage as a reference signal. The components are displayed on an X, Y_1, Y_2 plotter as a function of time. Also, as mentioned in the controller section, there are D to A outputs on the front panel that can be used to drive an X, Y_1, Y_2 plotter.

The receiver has available on the front panel FM carriers for temperature, electric field and compass to be recorded on an HP 3960 or similar instrumentation recorder for backup. The FM signals can be played back through the front panel connectors to reprocess a drop any time it is needed.

D. SOFTWARE

HP 9845T BASIC language programs are described here. DXGET is for acquisition, DXPRO for processing, SPLOT for series plotting, CROSS for cross-correlation, structure-function, and coherence. Listings and sample runs are found in Appendix A.

1. Acquisition--DXGET

DXGET accepts a user-specified number of data scans (one repetition of all variables) from the digital receiver. The computer's real-time clock is sampled just before starting the single DMA ENTER statement into the integer data array, Din(*). Because ENTER must run to completion, the 8 Hz default in the receiver must be on. The program was kept very simple so as not to risk data loss.

After the data are ENTER'd, the user enters comments and the file name. The data are then written to mass-storage, either floppy disc or tape cartridge.

2. XTVP Signal and Data Processing Description

The XTVP probe and digital receiver transfer functions are described to provide a basis for the application of a signal model. Careful attention to gains, phases and timing is required to determine oceanic water velocity profiles accurately.

The probe input stages shown in Fig. 2 can be described with three transfer functions for electric field, fall speed correction and compass coil:

$$
\begin{aligned}
G_{EF2} &= \frac{E_7}{E_E} , \\
G_{COR2} &= \frac{E_7}{E_C} , \\
G_{CC2} &= \frac{E_8}{E_C} .
\end{aligned}
\qquad (8)
$$

Estimated gains and phases are functions of frequency and typically are represented as phasors, $G = G_a \angle G_p$, where G_a is the magnitude of G and G_p is the phase of G.

Voltage to frequency (V/F) converter factors in the probe are

$$G_{EFVF} = \frac{F_E}{E_7} \quad (\mathrm{Hz/V}) \,,$$

$$G_{CCVF} = \frac{F_C}{E_8} \quad (\mathrm{Hz/V}) \,. \tag{9}$$

Solving for the probe inputs as a function of outputs yields

$$E_E = \frac{F_E}{G_{EFVF}\, G_{EF2}} - E_C \frac{G_{COR2}}{G_{EF2}} \,,$$

$$E_C = \frac{F_C}{G_{CCVF}\, G_{CC2}} \,, \tag{10}$$

where all quantities are complex because both amplitude and phase are needed.

Gain amplitudes for each probe are measured during manufacture; phases are estimated from a transfer function analysis using nominal component values. The analog gains measured at 7 Hz are

$$G_{EF} = E_7/E_E \,,$$

$$G_{COR} = E_7/E_C \,, \tag{11}$$

$$G_{CC} = E_8/E_C \,.$$

These choices of output measurement points introduce some loading effects because E_7 and E_8 are rather high impedance. The loading is estimated from nominal component values.

The voltage-to-frequency converters are calibrated statically. Our analysis shows a negligible phase angle.

The digital receiver response to input is described in terms of a timing diagram (Fig. 7). The counter start, stop and up-to-down times (t_o, ..., t_5) are developed from the zero-crossing detector output CR and the rotation periods T_{n-1} and T_n.

The in-phase (I), quadrature (Q) and baseline (B) counter outputs (Fig. 6) are signed summations of the number of cycles of the phase lock loop (PLL) output that are counted during the counter reference signals CIR and CQR. Approximating the summations by integrals simplifies analysis. The following generation formulae are for the n^{th} rotation, where N is the appropriate PLL frequency multiplier and F(t) is the frequency input to the PLL:

$$
\begin{aligned}
I_n &= N \int_{t_o}^{t_2} F(t)\, dt - N \int_{t_2}^{t_4} F(t)\, dt \,, \\
Q_n &= N \int_{t_1}^{t_3} F(t)\, dt - N \int_{t_3}^{t_5} F(t)\, dt \,, \qquad (12) \\
B_n &= N \int_{t_0}^{t_4} F(t)\, dt \,.
\end{aligned}
$$

The times when the counter reference timing generator changes the states of CIR and CQR are

$$
\begin{aligned}
t_0 &= 0 \,, \\
t_1 &= \frac{1}{4} T_{n-1} \,, \\
t_2 &= \frac{1}{2} T_{n-1} \,, \\
t_3 &= \frac{3}{4} T_{n-1} \,, \qquad (13) \\
t_4 &= T_n \,, \\
t_5 &= \frac{5}{4} T_n \,.
\end{aligned}
$$

Note that there is a significant phase shift between V_c and CR. Thus Q_n of the coil signal is nonzero.

The present processing models probe carrier frequencies for electric field and compass coil channels as follows:

$$F(t) = A\cos(\omega t + \phi) + C + Dt + Et^2 + \text{noise},$$

where A and ϕ are the amplitude and phase of the probe carrier frequency modulation and ω is the probe's radian rotation frequency. C, D and E allow for the exponential impulse response of the probe filters τ_1, τ_2, τ_3 (Fig. 2).

Expanding I, Q and B according to F(t) we have

$$\begin{aligned}
I_n = {} & 2N[\tfrac{A}{\omega}\sin(\omega t_2 + \phi) + Ct_2 + \tfrac{1}{2}Dt_2^2 + \tfrac{1}{3}Et_2^3] \\
& -N[\tfrac{A}{\omega}\sin(\omega t_0 + \phi) + Ct_0 + \tfrac{1}{2}Dt_0^2 + \tfrac{1}{3}Et_0^3] \\
& -N[\tfrac{A}{\omega}\sin(\omega t_4 + \phi) + Ct_4 + \tfrac{1}{2}Dt_4^2 + \tfrac{1}{3}Et_4^3],
\end{aligned}$$

$$\begin{aligned}
Q_n = {} & 2N[\tfrac{A}{\omega}\sin(\omega t_3 + \phi) + Ct_3 + \tfrac{1}{2}Dt_3^2 + \tfrac{1}{3}Et_3^3] \\
& -N[\tfrac{A}{\omega}\sin(\omega t_1 + \phi) + Ct_1 + \tfrac{1}{2}Dt_1^2 + \tfrac{1}{3}Et_1^3] \qquad (14) \\
& -N[\tfrac{A}{\omega}\sin(\omega t_5 + \phi) + Ct_5 + \tfrac{1}{2}Dt_5^2 + \tfrac{1}{3}Et_5^3],
\end{aligned}$$

$$\begin{aligned}
B_n = {} & N[\tfrac{A}{\omega}\sin(\omega t_4 + \phi) + Ct_4 + \tfrac{1}{2}Dt_4^2 + \tfrac{1}{3}Et_4^3] \\
& -N[\tfrac{A}{\omega}\sin(\omega t_0 + \phi) + Ct_0 + \tfrac{1}{2}Dt_0^2 + \tfrac{1}{3}Et_0^3].
\end{aligned}$$

Time variations in ω significantly influence the counter outputs. In general, one must use the exact time intervals when processing. The

time intervals for I_n and B_n are the same (t_0, t_2, t_4), while those for Q_n are 1/4 cycle later (t_1, t_3, t_5). Normalization of counter outputs thus requires separate T_{In} and T_{Qn}:

$$
\begin{aligned}
T_{In} &= T_n \, , \\
T_{Qn} &= 5/4 \; T_n - 1/4 \; T_{n-1} \, , \qquad (15) \\
T_{Bn} &= T_n \, .
\end{aligned}
$$

However, ω in the sinusoidal arguments is approximated by $\omega = 2\pi/T_n$, with a further approximation of $T_n/T_{n-1} = 1$ which results in

$$\omega t_i = \frac{\pi}{2} i \, , \quad i = 1, \ldots, 5 \, . \qquad (16)$$

The measured rms deviations of T_n/T_{n-1} appear to be bounded by 0.5% which roughly corresponds to 0.5% rms noise in I and Q. This seems acceptable at present.

In any case, this noise is included in the velocity error estimated from I'_n and Q'_n noise (see Eq. 19). Thus we can write, using $\omega = 2\pi/T$:

$$
\begin{aligned}
\frac{I_n}{N} &= -\frac{4A}{2\pi} T_{In} \sin\phi + C(T_{n-1} - T_n) \\
&\quad + D(1/2 \; T_{n-1}{}^2 - T_n{}^2)/2 + E(1/4 \; T_{n-1}{}^3 - T_n{}^3)/3 \, , \\
\frac{Q_n}{N} &= -\frac{4A}{2\pi} T_{Qn} \cos\phi + C(T_{n-1} - T_n)5/4 \\
&\quad + D(17 \; T_{n-1}{}^2 - 25 \; T_n{}^2)/32 \qquad (17) \\
&\quad + E(53 \; T_{n-1}{}^3 - 125 \; T_n{}^3)/192 \, , \\
\frac{B_n}{N} &= C \; T_n + 1/2 \; D \; T_n{}^2 + 1/3 \; E \; T_n{}^3 \, .
\end{aligned}
$$

To solve for A and ϕ we find C, D and E from B_{n-1}, B_n, and B_{n+1} by solving a linear 3x3 matrix equation. The other values of B are:

$$\frac{B_{n-1}}{N} = C\ T_{n-1} - 1/2\ D\ T_{n-1}^2 + 1/3\ E\ T_{n-1}^3\ ,$$

$$\frac{B_{n+1}}{N} = C\ T_{n+1} + D\ (T_n T_{n+1} + 1/2\ T_{n+1}^2) + 1/3\ E\ [(T_n + T_{n+1})^3 - T_n^3]\ . \tag{18}$$

The corrected in-phase and quadrature results can then be determined:

$$I_n' = -\frac{4ANT_{In}}{2\pi}\sin\phi\ ,$$

$$Q_n' = -\frac{4ANT_{Qn}}{2\pi}\cos\phi\ . \tag{19}$$

To obtain averaged FM amplitude and phase, we convert to rectangular coordinates:

$$F_I = -A\sin\phi = \frac{2\pi}{4NT_{In}}I_n'\ ,$$

$$F_Q = -A\cos\phi = \frac{2\pi}{4NT_{Qn}}Q_n'\ . \tag{20}$$

Then we filter using a Bartlet (i.e., triangular) window with weights w_n:

$$\overline{F_I} = \frac{2\pi}{4N}\sum_{n=1}^{Nav} w_n I_n'/T_{In}\ ,$$

$$\overline{F_Q} = \frac{2\pi}{4N}\sum_{n=1}^{Nav} w_n B_n/T_{Bn}\ . \tag{21}$$

Baseline carrier frequencies are computed similarly:

$$\overline{F_B} = 1/N \sum_{n=1}^{Nav} w_n B_n / T_{Bn} \quad . \tag{22}$$

Averaged amplitude F_a and phase F_p are found from $\overline{F_I}$ and $\overline{F_Q}$ by converting to polar coordinates using a four-quadrant arctangent function:

$$\begin{aligned} F_a &= (\overline{F}_I{}^2 + \overline{F}_Q{}^2)^{1/2} \ , \\ F_p &= \tan^{-1} \frac{-\overline{F}_I}{-\overline{F}_Q} \ . \end{aligned} \tag{23}$$

Thus an input signal of $\cos(\omega t + \phi)$ will result in $F_p = \phi$. When $\phi > 0$, the input signal leads $\cos(\omega t)$. The reference is the zero-crossing-detector output CR.

Using phasor notation we write the complex frequency deviation in terms of amplitude and phase for both the electric field and compass coil.

$$\begin{aligned} F_E &= F_{Ea} \angle F_{Ep} \ , \\ F_C &= F_{Ca} \angle F_{Ep} \ . \end{aligned} \tag{24}$$

Using (10) we compute the complex voltages at the probe input:

$$\begin{aligned} E_E &= E_{Ea} \angle E_{Ep} \ , \\ E_C &= E_{Ca} \angle E_{Cp} \ . \end{aligned} \tag{25}$$

The east and north velocities are found as

$$u = \frac{E_{Ea}}{F_z L(1+C_1)} \cos\psi \ ,$$

$$v = -\frac{E_{Ea}}{F_z L(1+C_1)} \sin\psi + W \ \frac{F_H}{F_z} \frac{(1+C_2)}{(1+C_1)} \ , \tag{26}$$

where

$$\psi = \beta_E - \beta_C + \pi/2 + \alpha \ ,$$

$$\beta_E = - E_{EP} \ ,$$

$$\beta_C = - E_{CP} \ , \tag{27}$$

$$\alpha = \pi \ .$$

W is the estimated fall rate, dz/dt, of the probe computed from a depth versus time polynomial.

Depth versus time was measured using five special probes with pressure transducers instead of thermistors. An average quadratic was fit to these measurements for use in determining Z and W versus time during processing.

$$P = -Z = 3.1 + 4.544t - 0.0006749t^2. \tag{28}$$

A "tilt" correction (discussed in section V.C.) is applied to the north velocity component to remove effects caused by north-south probe tilt. The "area" A of the coil is computed assuming no probe tilt:

$$A = \frac{E_C T}{2\pi F_H} \ , \tag{29}$$

where T is the rotation period, E_C is the coil signal, and F_H is the earth's horizontal magnetic field.

Individual corrected estimates of the north velocity component are found by using

$$V = -\frac{E_{EA}}{F_z L(1+C_1)} \sin\psi + W \frac{F_H(1+C_2)}{F_z(1+C_1)} \frac{A}{\bar{A}} , \qquad (30)$$

where $\bar{A}$ is the vertical mean of A.

3. Plotting and Analysis Programs

a. SPLOT

SPLOT is used to obtain more insight into the profiles. It plots a series of U, V profiles with various processing applied. Generally a quadratic fit is performed on the profile to obtain the residuals. These can be rotated to a given time by specifying the inertial period and the time of each profile. Cartesian or polar displays are available. One can also plot the fits.

b. CROSS

CROSS will compute cross-correlations, structure functions, or coherences between U and V profiles. Input is set up in advance, and then processing continues unattended. Many sets and combinations of files can be processed in a single run.

E. PROBE CALIBRATIONS

1. Sippican's Calibration

The XTVP gains $G_{EF} = E_7/E_E$, $G_{COR} = E_7/E_C$, $G_{CC} = E_8/E_C$, $G_{EFVP} = F_E/E_7$ and $G_{CCVF} = F_C/E_8$ are measured during manufacture before potting. Figure 9 shows the test setup to obtain G_{EF}, G_{COR}, and G_{CC}. The operator adjusts the quadrature potentiometer $P = R_7/(R_6 + R_7)$ and the resistance box R_2 to obtain a null reading on both the I and Q meters of the PAR 129. This forces

$$G_{ATTEN} \cdot G_{PROBE} = 1 \angle \phi_{PAR} , \qquad (31)$$

where ϕ_{PAR} is the phase offset of the PAR 129. The Sippican calibration estimates $G_{PROBE} = R_2 + 100$, which is a result of considering only the resistive part of the attenuator. Further analysis of the attenuator transfer function shows that this estimate is about 3% too large for G_{EF} and G_{COR} because approximately 15° phase angles exist at 7 Hz. The exact error depends on ϕ_{PAR}. Table 3 shows results of the analysis where P and R_2 were adjusted to obtain analytic probe gains and phases.

Table 3.

	$P = R_7/(R_6+R_7)$	R_2	$\frac{1}{\lvert G_{ATTEN}\rvert}$	$-\phi_{ATTEN}$	% error of $R_2 + 100$
G_{EF}	0.0244	25278	24495	15.2°	3.5%
G_{COR}	0.525	1036	1097	15.3°	3.5%
G_{CC}	0.011	3598	3698	1.0°	0.0%

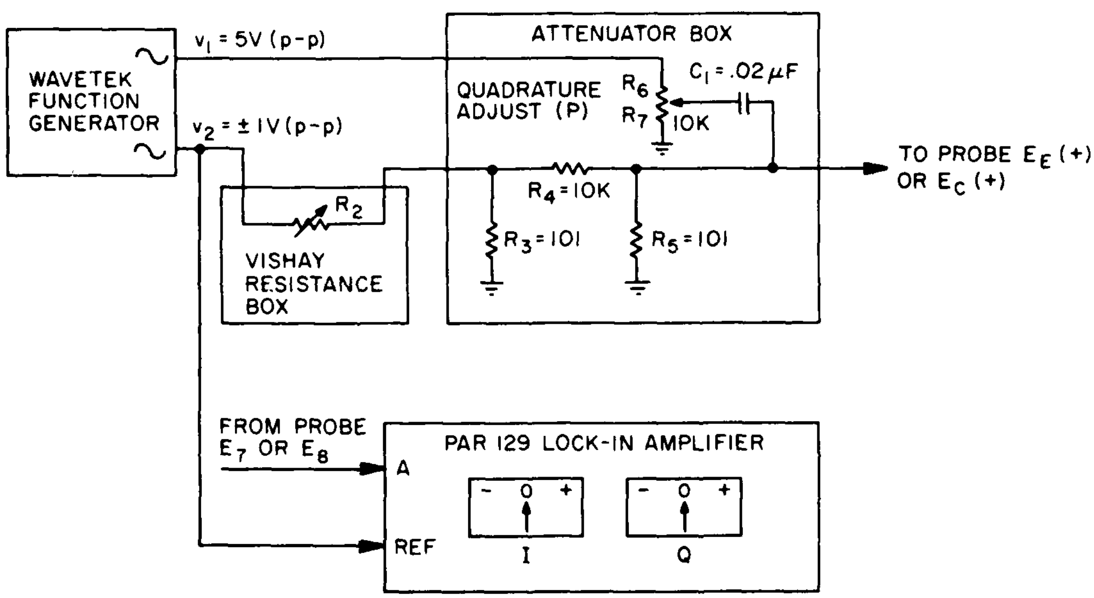

Figure 9. Standard setup used by Sippican for probe calibrations.

These estimates assume $\phi_{PAR} = 0$. Our PAR 129 indicates -3° to -5° with dials set to 0°. Sippican's PAR 5204 indicates a value closer to 0°. For correct results, the PAR dials should be set so that the Q meter indicates zero for the signal equal to the reference.

Obtaining the correct G_{PROBE} requires knowledge of the quadrature adjust potentiometer P, which is not recorded. However, if ϕ_{PAR} is zero, we can estimate ϕ_{ATTEN} from a ϕ_{PROBE} obtained from a transfer function analysis of a typical probe.

From the computer analysis of the attenuator gain we find that $1/(R_2 + 100)$ approximates the real part of G_{ATTEN} quite closely. Thus a better estimate for the gain magnitude of the probe is

$$|G_{PROBE}| = (R_2 + 100) \cos(\phi_{PROBE}) \quad . \tag{32}$$

G_{EFVP} and G_{CCVF} are found statically by applying +0.5 V and then -0.5 V to both E_7 and E_8 while recording the voltage-to-frequency converter output frequencies F_E and F_C. The change in frequency divided by the change in voltage provides the estimate for G_{EFVP} and G_{CCVF}.

Early calibrations had a 1K resistor in series with the ±0.5 V source. Thus the early Sippican G_{EFVF} and G_{CCVF} estimates were low by 3.3% and 1.7%, respectively. In May 1980 the 1K resistor was removed from the setup.

2. <u>APL-UW's Calibrations</u>

The calibrations described in the previous section are time consuming. A simplified calibration procedure is used by Sippican Corp. in the manufacture of XCP's. We wanted to verify their calibrations to eliminate uncertainties in the velocity determination. We also wanted to be able to correct old calibrations by finding any systematic differences. Therefore, ten unpotted, Sippican-calibrated probes were purchased for our measurements.

Our calibrations (Fig. 10) were done with both channels of the probe having nominal signal amplitudes at all times rather than setting one channel to zero input while measuring the other as Sippican did. Our input signals were exactly in phase however, due to lack of test equipment. (We would have liked to check for cross-talk and nonlinearity.)

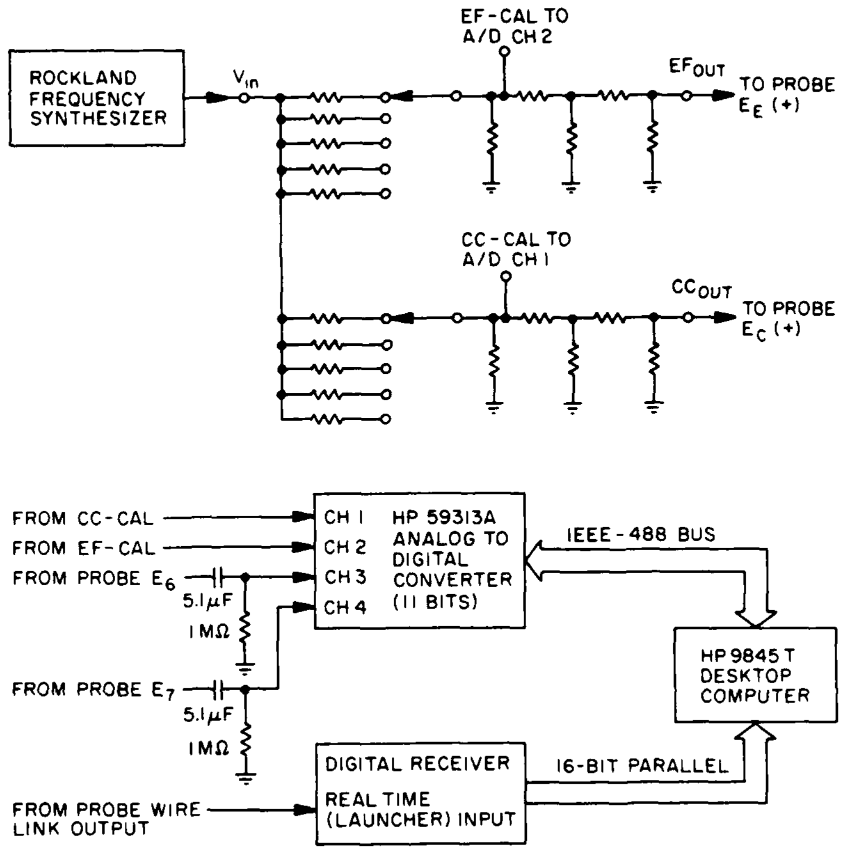

Figure 10. Special setup used by APL-UW for probe calibrations.

To check the Sippican calibrations, we wanted to measure the probe at the same points. However, this meant loading E_7 and E_8 (Fig. 2) and thus changing the overall transfer functions. We therefore measured at E_5 and E_6, and estimated the transfer functions to E_7 and E_8.

Note that in the future these intermediate points need not be measured; only the three overall transfer functions, $G_{EF}\,G_{EFVF}$, $G_{COR}G_{EFVF}$, and $G_{CC}G_{CCVF}$ will be needed.

Because only single-ended test signals with a common reference were available, the drive signal should go to the "plus" (noninverting) inputs of E_E and E_C. This procedure reduces drive signal loading and tests all the components.

The measurement points EFCAL and CCCAL are needed since there is significant interaction between the two attenuator-adjust switches. The attenuations from EFCAL and CCCAL to EFOUT and CCOUT are estimated stagewise using a dc source and a digital voltmeter.

The ac coupling to channels 3 and 4 of the HP 59313A digitizer isolates its input bias current from the probe. These transfer functions are allowed for in the analysis.

The HP 59313A digitizer multiplexes the analog to digital converter between four input channels. The time differences between channels are corrected by adjusting the phase angles of the sinusoidal fits during analysis.

The digital receiver is used in the real-time mode. The acquisition program sets up a direct memory access from the receiver. This runs concurrently with input from the digitizer. Each channel's sample rate is limited to 5 Hz by the speed of the HP 9845 desk-top computer.

Operation is not fully automatic due to lack of equipment: the operator is required to change the attenuator settings manually for each "set" in a "run." Typically, four linearly independent sets of attenuater settings are used per calibration run, although the program can handle nine sets.

Following acquisition, the processing runs unattended for several minutes to compute gain estimates for that run. We made from 5 to 15 runs per probe to observe the variability of the method and obtain reliable results.

To obtain amplitudes and phases of the digitizer channels, they are least-squares fit to

$$a_1 + a_2 \cos\omega t + a_3 \sin\omega t + a_4(t-\bar{t}) \ , \tag{33}$$

where ω is the radian frequency, $\bar{t}$ is the mean t and $a_1, \ldots, a_4$ are the coefficients determined by the "set." ω is found by iterative adjustment to obtain phase continuity between successive blocks of the CC-CAL channel. The procedure is identical to that described by Sanford et al. (1978). The amplitude A and phase ϕ are

$$A = (a_2{}^2 + a_3{}^2)^{1/2} ,$$

$$\phi = - \tan^{-1} \frac{a_3}{a_2} . \tag{34}$$

The amplitude and phase angle of each sinusoidal fit and the average I and Q from the receiver were then least-squares fit to a linear model of complex probe gains:

$$\begin{aligned}
E_7 &= G_{EF}\ E_E + G_{COR}\ E_C ,\\
E_8 &= G_{CC}\ E_C ,\\
F_E &= G_{EFVF}\ E_7 ,\\
F_C &= G_{CCVF}\ E_8 ,\\
F_E &= (GEFVF\ G_{EF})\ E_E + (G_{COR}\ G_{EFVF})\ E_C ,\\
F_C &= (G_{CC}\ G_{CCVF})\ E_C .
\end{aligned} \tag{35}$$

The first four expressions are to be compared with Sippican's, while the last two are used to find the overall transfer functions of the probe.

The receiver counters average over each revolution, so the measured F_E and F_C are quieter than E_7 and E_8 which are only sampled once per 200 ms. Thus, the overall transfer functions can be determined more accurately and with less effort than the individual transfer functions.

The circuit gains (e.g., G_{EFVF}) are complex coefficients a_j in models of the form

$$y = \sum_{j=1}^{m} a_j\ x_j , \tag{36}$$

where y is the output and the x_j's are the inputs.

To solve for the a_j's, several linearly-independent "sets" of y versus x_j are required. Each measured output y_i is related to the inputs x_{ij} as follows:

$$y_i = \sum_{j=1}^{m} a_j x_{ij} + r_i, \qquad \text{for } i = 1, \ldots, n \tag{37}$$

where n is the number of sets and the r_i are the residuals. The complex gains a_j are found by least-squares fitting in a manner similar to the sinusoidal fitting.

For each probe, the gains were averaged over a number of runs. These averages include only those runs with low fit noise and low receiver noise.

Multiple short runs enabled elimination of bad sections of data instead of repeating an entire long run. Multiple runs also allowed an estimation of the reliability of the method. The sinusoidal fits are less sensitive to the rotation frequency estimate when the fits are shorter.

Our measurements indicate that the complex gains from probe to probe are quite similar, within 0.4% in magnitude and 0.4° in phase, as summarized in the standard deviations in Table 4.

Table 4.

	Amplitude Deviation from Analytic (%)		Phase Deviation from Analytic (°)	
	Avg.	Std. Dev.	Avg.	Std. Dev.
G_{EF}	0.2	0.1	- 0.2	0.2
G_{COR}	-1.6	0.4	- 0.1	0.4
G_{CC}	-1.8	0.1	- 0.3	0.0

Note, however, that the averages for G_{COR} and G_{CC} amplitudes differ significantly from the analytic estimates.

Our measurements deviate from Sippican's using $|G_{PROBE}| = (R_2+100) \cos(\phi_{PROBE})$ as summarized in Table 5.

Table 5.

Amplitude
Deviation from
Sippican's (%)

	Avg.	Std. Dev.
G_{EF}	0.6	0.1
G_{COR}	1.3	0.5
G_{CC}	0.2	0.2

The G_{EF} and G_{COR} errors are significant and would be smaller if the Sippican PAR phase error were 1° as summarized in the following table.

Table 6.

Amplitude Deviation (%)
from Sippican's Assuming
1° PAR Error

	Avg.	Std. dev.
G_{EF}	0.0	0.1
G_{COR}	0.8	0.5
G_{CC}	0.2	0.2

Our estimates of G_{EFVF} and G_{CCVF} show relatively small variability from probe to probe compared with Sippican's measurements for the same nine probes. The following table summarizes.

Table 7.

	Our V/F Estimates		Sippican's V/F Estimates Allowing for 1K Resistor		Deviations of Our Estimates From Sippican's
	Avg. (Hz/volt)	Std. Dev. (%)	Avg. (Hz/volt)	Std. Dev. (%)	(%)
G_{EFVF}	994	0.2	1000	1.0	-0.6
G_{CCVF}	1001	0.1	1000	0.6	0.1

The general conclusion about the calibration problem is that future designs should eliminate the need for calibration, or, if needed, make it automatic with frequent verification of the test setup.

We have not attempted to answer the question of how the calibrations change with potting or depth. There is some reason to believe potting may affect the V/F converter calibration. We have not determined why the measured gains differ from the analytic estimates.

F. SENSITIVITY ANALYSIS OF PROBE

Sensitivity analysis of the XTVP probe is performed using the analytic transfer functions for the probe while varying the component values. We have not shown sensitivities for individual components; rather we have computed the variability of the probe transfer functions as a function of component tolerances. We have not shown statistics for the V/F converters.

The component tolerances are used to choose random component values. Uniform distributions were used for simplicity. Typically 20 realizations of the transfer function with independent random component values are used.

The maximum, minimum, average and standard deviation for the amplitude and phase of each transfer function are computed given the rotation frequency and component tolerances using a computer program.

Table 8 shows deviations at 7 Hz using standard component tolerances of 0.1% resistors and 10% capacitors.

Table 8.

	Amplitude			Phase		
	Avg.	rms(%)	Max-Min(%)	Avg.	rms(%)	Max-in(%)
G_{EF}	24333	0.13	0.28	15.2	0.5	2.1
G_{COR}	1096	0.15	0.26	-165.0	0.5	2.0
G_{CC}	3696	0.13	0.22	-179.0	0.06	0.21

If 1% resistors and 10% capacitors are used, the amplitude deviations increase while the phase deviations remain the same, as can be seen in the following table.

Table 9.

	Amplitude			Phase		
	Avg.	rms(%)	Max-Min(%)	Avg.	rms(%)	Max-Min(%)
G_{EF}	24568	1.1	5.0	15.2	0.5	2.0
G_{COR}	1094	1.7	5.9	-165.0	0.5	2.0
G_{CC}	3682	1.2	4.0	-179.0	0.05	0.25

An attempt to determine the pressure variability uses 0.5% capacitor deviations and no resistor deviations (Table 10).

Table 10.

	Amplitude			Phase		
	Avg.	rms(%)	Max-Min(%)	Avg.	rms(%)	Max-Min(%)
G_{EF}	24494	0.00	0.00	15.2	0.005	0.02
G_{COR}	1097	0.00	0.01	-165.1	0.005	0.02
G_{CC}	3697	0.00	0.00	-179.0	0.001	0.002

IV. Operations

A. EQUIPMENT INVENTORY

Table 11 lists the equipment that was shipped to support the deployment of about 50 XTVP's from the USNS Kane.

Table 11.

Box #		Contents	Function	Weight (lb)
1.	a)	PAR Lock-in Amplifier	Resolves analog U and V velocity components	
	b)	HP 3960 Analog Tape Recorder	Records FM signals during drop	
	c)	Sippican Digital Receiver	Determines digital U and V velocity components; sends data to 9845 computer	291
2.	a)	Tektronix TM506 Mainframe 1) PS 503A Power Supply incl. 2) FG 501 Function Generator 3) DC 503 Counter/Timer 4) DM 501 Multimeter 5) SC 502 Oscilloscope	Repair and calibration equipment	
	b)	HP 3964 Analog Tape Recorder	Spare recorder for FM signal storage	
	c)	APL-UW Digital Receiver	Spare receiver to Sippican made unit	
	d)	HP 7046A XYY Plotter	Analog plotter for real time display	305 (total)
3.	a)	HP 9845T Computer (CRT)	Digital acquisition and processing	50

Box #		Contents	Function	Weight (lb)
4.	a)	HP 9845T Computer (CPU)	Digital acquisition and processing	101
5.	a)	HP 9872A Plotter	Plots digital U,V profiles	94
6.	a)	HP 9885M Disk Drive	Digital storage for raw and processed profiles	128
7.	a)	HP 98034A HP-IB Interface	9845T computer peripheral and interface cards	
	b)	HP 98035A Opt. 100 Real Time Clock		
	c)	HP 98032A 16-bit I/O APL-UW		
	d)	HP 98032A 16-bit I/O Sipp. DR		
	e)	Fluke 8024A Multimeter	Test	
	f)	HP 32E Calculator	Hand calculator	
	g)	Misc. Electronic Spares	Repair	75
8-10.	a)	Floats (Ethofoam) (3 boxes used because of bulk)	For XTVP surface flotation (Total 3 boxes)	50
11.	a)	Misc. Support Equipment	--	100
12.	a)	10 Mag. Tapes for Analog Recording	Supplies	
	b)	50 Cassettes for Digital Recording	"	
	c)	4 boxes Graph Paper for Analog Plots	"	
	d)	1 box Xerox Paper	"	109
13.	a)	10 Mag. Tapes for Analog Recording	Supplies	
	b)	25 Diskettes (8 1/2" IBM) for Digital Recording	"	
	c)	4 boxes Graph Paper for Digital Plots	"	
	d)	1 box Xerox Paper	"	
	e)	1 Tool Box - Misc. Hand Tools	"	
	f)	1 XTVP Log Book	"	84

Box #		Contents	Function	Weight (lb)
14.	a)	Tektronix 7603R Oscilloscope	FM data display	
	b)	7A22 Plug-In Amplifier	"	
	c)	7A26 Plug-In Amplifier	"	
	d)	7B23 Plug-In Time Base	"	85
15.	a)	Launcher Tube Ends	For launching tube assembly	
	b)	Adaptor Tubes		
	c)	Metal Hose Clamps and Hardware		73
16.	a)	2 Sippican Hand Launchers	XTVP launcher	
	b)	Deck Cable	"	
	c)	Misc. Cables	"	
	d)	Scope Probes	"	89
17.	a)	1 Garbage Can	For on-deck check	
	b)	Anti-hypothermia Suits	Personnel protection	24
18.	a)	5 LEXAN Tubes, 2 1/2" x 9'	For deck launcher	10
19.	a)	Box Misc. Stores		57
20.	a)	Probes (12/box)		50
21.	a)	Probes		50
22.	a)	Probes		50
23.	a)	Probes		50
		TOTAL SHIPPING WEIGHT		1,925

This equipment comprises both analog and digital processing instrumentation including spare data receivers, analog tape recorders and launch hardware.

B. INSTALLATION OF XTVP SHIPBOARD LAUNCH AND RECEIVING SYSTEM

1. Deck Setup

a. Determine exact weather deck location where probes will be launched. Some (but not all) of the factors that will fix this position are:

1) Concurrence of Chief Scientist and Chief Bos'n (or equivalents)
2) Consideration of other scientific projects on same cruise
3) Distance from assigned laboratory space
4) Type of ship
5) Wind/weather expected, and its influence on launching operations
6) Sufficient space aft of launcher loading position to swing launcher tube inboard in order to load probes and attach flotation collars.

b. Assemble LEXAN launcher tube (usually two 9' sections are enough, unless ship's rail is >10' above waterline). Attach launcher loading end to ship's rail (Pos. A) so outer end can be swung inboard for loading and outboard for launching. Attach all necessary support and securing lines. Prepare a release line and leave coiled at point where launcher end is brought inboard (Pos. B). Secure a 30 gal. plastic garbage can at ship's rail at (Pos. A). Fill to ~16" with clean seawater.

c. The Sippican hand launcher and intercom (currently Radio Shack # 43-221) are needed at Pos. A.

1) The hand launcher is usually hung on a bulkhead hook or equivalent, to protect it when not used in the launching tube, with about 10' of slack cable to enable probes to be tested in the plastic bucket.

2) The intercom is secured in a suitable location at about head height, using a convenient stanchion or bulkhead. Note that this unit is not waterproof. During inclement weather or high sea states it should be stored in the lab when not being used; thus a "shock cord" (quick release) type of attachment should be used.

d. The launcher and intercom wires must be routed to the lab operating area. Considerable care must be taken to avoid hazards that may injure the wires. If possible, an overhead or bulkhead route is preferable to a deck route.

2. Laboratory Setup

a. Determine from Chief Scientist the maximum available bench and deck space.

b. Set up communications link to bridge (mandatory), and radio room and chartroom if possible.

c. Bench space allocation should be:

1) HP 9845T computer ~20" wide
2) HP 9872A digital plotter and HP 9885M disc drive are mounted together vertically ~20" wide
3) HP 7046B analog plotter (if used) ~19" wide
4) Approximately 30" of bench area for writing
5) If more bench space available, some of the following items listed as rack mounted may be used in 36" high racks which can usually be mounted on top of the bench.

d. Rack space. The following is a "top-to-bottom" guide.

1) HP 3964 analog tape recorder - must be accessible to load and unload tapes.
2) PAR 129A lock-in amplifier - occasional changes in control settings will be made on this unit.
3) Tektronix TM 506 mainframe scope - check to ensure electric field and compass signals are present.
4) XTVP digital receiver - once connected, usually no changes need be made to this unit.

e. If additional rack space is available, the backup HP 3960 analog tape recorder and XTVP-DR should be mounted so as to allow a quick switch if the primary units malfunction.

f. Boxes of expendable supplies (probes, magnetic tape, plotting paper, etc.) should be stored in the lab area if possible for easy access during the cruise. Boxes of spare parts or seldom used items may be stored in a hold or other nonlab area.

g. Before sailing, all items must be properly secured in accordance with good seamanlike practice. The Chief Boatswain (or equivalent) can advise and assist, and may be able to suggest improvements, etc.

h. Try to do a dummy drop, testing a probe in a bucket, etc. and communicating with bridge, radio room, engine room, etc. before the cruise begins. All installations, rigging and testing are more easily done alongside the dock.

C. SUMMARY OF XTVP LAUNCH AND OPERATIONS

1. <u>General Instructions to Bridge</u>

   a. Establish communications channels.

   b. Emphasize radio silence for bridge and radio room.

   c. Emphasize speed requirements (must be less than 8 knots). In high winds, head into wind/seas to prevent paying out too much wire.

   d. Provide the bridge with written instructions and a copy of this summary if possible.

2. <u>Pre-Launch Procedure</u>

   a. Operator gives bridge desired position for next drop and asks for 5 minute warning.

   b. Launch person picks out a probe, writes serial number in the drop log, puts probe in hand launcher, removes magnet (turns on), puts probe into bucket of seawater and waves magnet in the vicinity of the electrodes (not to turn on and off, but to induce a signal in the coil channel). Lab confirms presence of FM carriers, and that V_C and V_E deviates with magnet. Launch person replaces magnet (turns off).

   c. When ready for launch, lab person comes to the deck to help put probe in launcher (a second person is needed to catch the probe as it falls down launch tube). Fuse and float are attached to the probe (see Appendix B), and then complete unit is secured in launcher. Lab person returns to the lab.

   d. Lab person puts voice header onto the analog magnetic tape (e.g., STREX '80, drop number, probe number), and loads acquisition program into HP 9845 computer.

   e. Bridge informs lab that the ship is on or approaching station.

   f. Lab acknowledges and requests radio silence for bridge and radio room.

   g. Lab informs deck to launch when ready.

3. Launch Operations

a. Deck operator informs lab that it's 10 seconds to launch, lights fuse, and hollers into intercom. Lab operator starts analog tape recorder, 9845 acquisition program, and elapsed time counter (model DC 503 timer-counter).

b. Fuse burns at 120 seconds per yard; 27 inches (about 80 to 90 seconds) was used during STREX.

c. The end of the fuse is bent at 90 degrees and thrust into the Ethafoam float to prevent the fuse from rotating. See Appendix B for construction details.

d. Launcher is lowered down toward the waves.

e. Operator waits for a high wave so that the probe will only drop 1 to 2 feet from the launcher into the water.

4. Data Acquisition and Processing

a. Turn on HP 9845 with AUTOST key locked down and the system cartridge in T15 (right-hand cartridge slot).

b. Press special function key "k_o" to load and start DXGET, the acquisition program. Press CONT again when probe is launched.

c. After the drop is completed, type the file name for the disk file to store data and add comments to the real time when DXGET was started.

d. Earth's magnetic field can be found using the PADOC program. PADOC requires the date and position as input.

e. To process the disk file, press special function key "k_1" to load and start DXPRO, the processing program. Answer the prompts with the appropriate file names and probe numbers. Add the drop and earth's magnetic field to the calibration data found on the XCAL file. Processing will take about 20 minutes to obtain a completed plot.

5. Post-Launch Procedure

a. Lab advises bridge that the probe has been dropped, and the time is entered in the bridge log.

b. Operator writes the time which appears on the 9845 CRT display.

c. Ship continues for 2 min at the same course and speed, after which it is told to come into the wind and sea and essentially maintain direction.

d. At the end of the drop, the wire breaks at the hand launcher so that no wire is left in the tube.

e. The XBT wire canister stays on launcher until next drop to protect launcher contacts.

f. The operator writes down the elapsed time from when the fuse was lit to the time the wire broke.

g. Operator logs the end-of-drop count from the analog tape recorder.

h. Operator notifies bridge that drop has been completed and that there is no need for further radio silence.

V. Error Analysis

A. CONTAMINATION OF XTVP PROFILES FROM VESSEL'S EM FIELDS

Contamination of XTVP velocity measurements is severe in the near vicinity of large research vessels. Based on the simple dipole character of vessel fields, our rule of thumb has been to release a probe 1-2 ship lengths away. This section describes some recent analyses to assess the amount of contamination found during two recent experiments.

Separation of vessel-caused disturbances from the desired motionally induced field is possible only because the former can be so large. Near the ship we frequently find electric currents that are interpreted as due to a velocity in excess of 10^3 cm/s. Since there are no ocean flows of this speed, we can assume this velocity is due to the vessel and compare it with a model.

The model used is a horizontally *oriented current* dipole at the sea surface aligned with the vessel. The idea here is that electric currents exist around the vessel because of corrosion and cathodic protection. The latter cause probably will be dipole-like and of rather small scale. The horizontal and vertical electric current density in the area would be

$$J_x = \frac{2p}{4\pi}(2x^2-z^2)/(x^2+z^2)^{5/2} , \tag{38}$$

$$J_z = \frac{6pxz/(x^2+z^2)^{5/2}}{4\pi} , \tag{39}$$

where p is the dipole strength in ampere meters. These expressions are twice those found for a dipole in an infinite medium because the current is confined to only the lower half domain.

For a ship speed of 5 knots and a fall speed of 4.5 m/s (say 10 knots), the horizontal position of the probe will increase at a rate of 0.5 W or $x = a + 0.5\ z$, where a is the distance of release from the center of the dipole.

The XTVP measures the horizontal component of the electric current as

$$J_x/\sigma = \frac{p(1+\xi-\xi^2/4)}{a^3\pi\sigma(1+\xi+5\xi^2/4)^{5/2}} , \qquad (40)$$

where σ is the electrical conductivity and $\xi = z/a$. The electric current is connected to velocity by the relation

$$V_y = J_x/F_z\sigma = \frac{p(1+\xi-\xi^2/4)}{a^3\pi F_z\sigma(1+\xi+5\xi^2/4)^{5/2}} \text{ m/s} . \qquad (41)$$

One aspect of this expression to note is that $J_x/\sigma = 0$ at a depth of $z = 2a(1+\sqrt{2}) = 4.8$ a. A near-surface notch, or low-signal zone, is frequently observed in the Kane and other near-vessel dropped profiles. This is because the electric currents lines are curved and must become vertical as they converge toward the source and sink. A probe will experience this zone of zero horizontal electric currents at a depth of z = 4.8 a. Thus we would expect it to be seen at deeper depths for large release separations. Note also that the sign of J_x changes at z = 4.8 a.

Figures 11 and 12 show two drops from the September 1979 Kane experiment. An example is shown for the SE-NW leg and for the NE-SW leg, two different orientations of the ship with respect to the earth's magnetic field. The absolute values of east (u: dashed), north (v: dash-dot) and speed $[(u^2 + v^2)^{1/2}$: solid] are plotted versus depth. The near-ship notch is seen in both figures, and a signal decay of about z^{-3} is observed as expected. At a depth of 30 m and deeper, the ocean-induced signal seems to dominate.

Figures 13 and 14 show two other drops, one from the remote launcher and another from the towed rubber boat. Neither of these profiles shows the vessel signature. They quickly converge on a signal level of 20-30 cm/s, which is the ocean contribution.

In Fig. 15, a comparison of the data of Fig. 11 is made with a fit [i.e., the absolute value of (41)] of the model for $p/\pi F_z\sigma = 4.9 \times 10^4$ which corresponds to p = 30.8 A-m, and for a = 1 m. A current dipole moment of this amount is typical for ships of this size. The model and data agree reasonably well until the ocean field takes over at 20 m. It should be emphasized that the model predicts >1 cm/s error until a depth of ~100 m.

Curves are of east (dashed), north (dash-dot) and speed (solid).

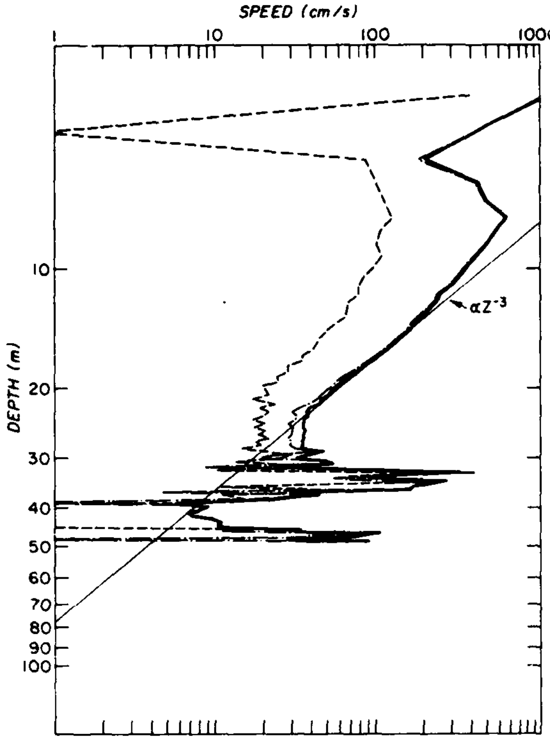

Figure 11. Drop 281 USNS Kane, deck launched. Dipole-like decay is shown as z^{-3}.

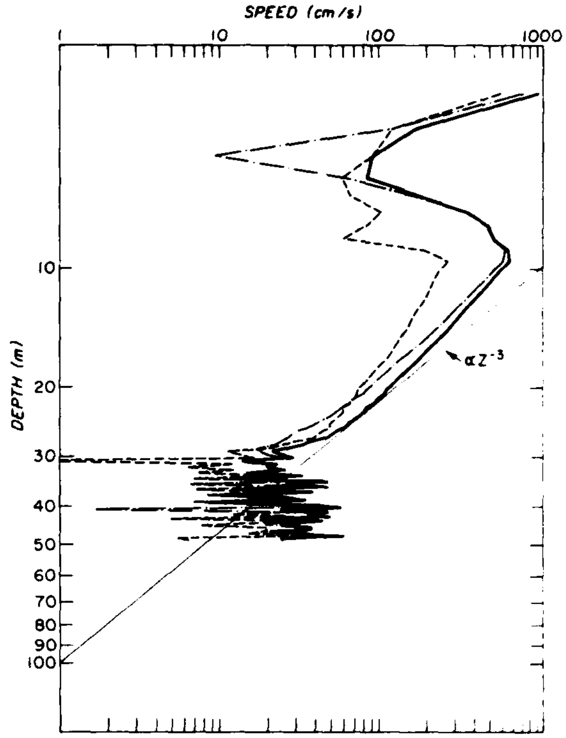

Figure 12. Drop 274 USNS Kane, deck launched. Dipole-like decay is shown as z^{-3}.

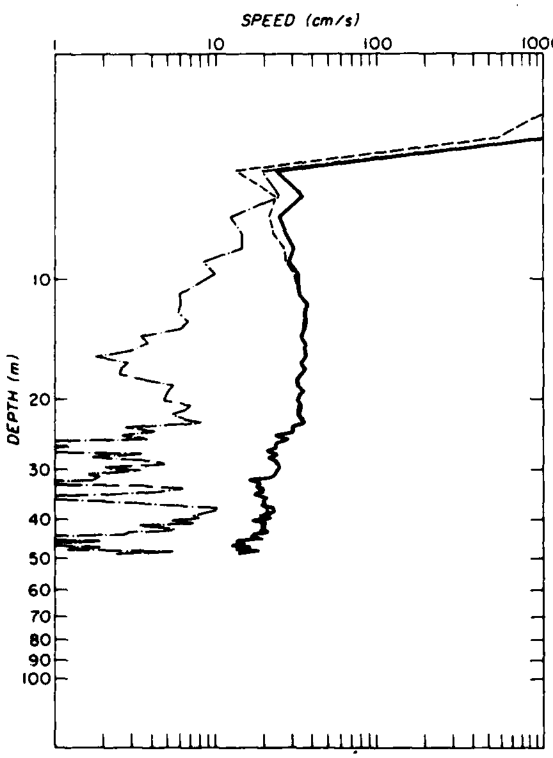

Figure 13. Drop 276 USNS Kane, remote launched.

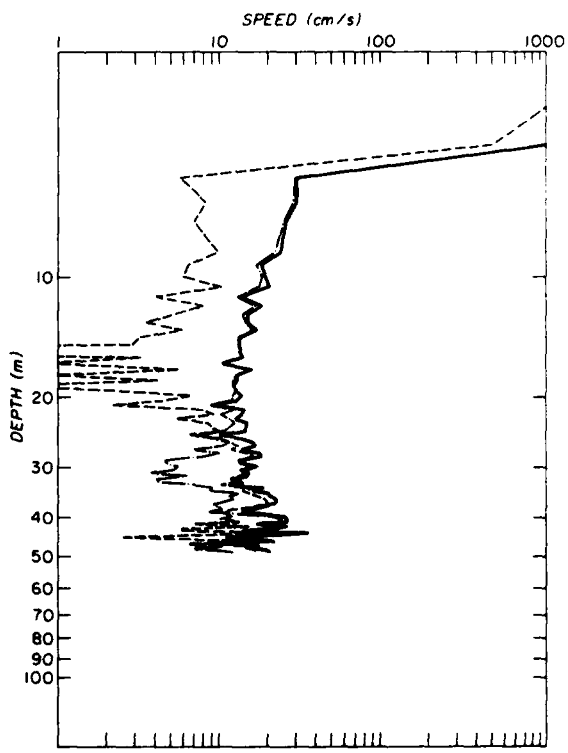

Figure 14. Drop 299 USNS Kane, rubber boat launched.

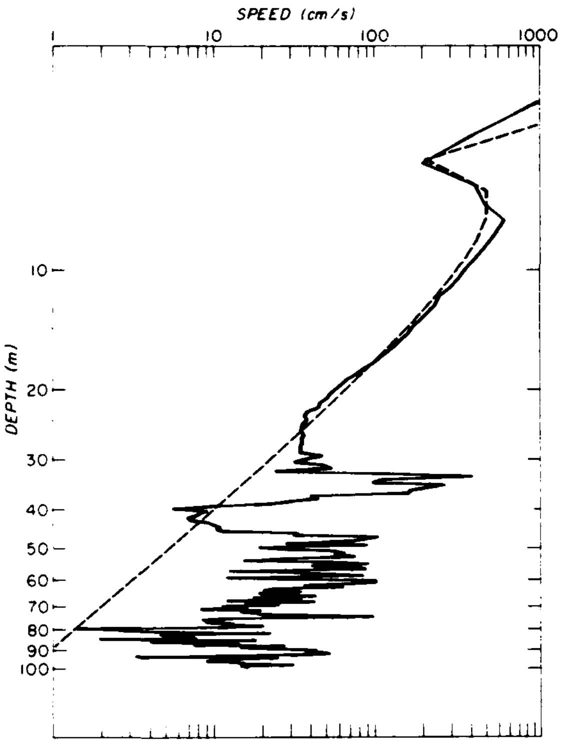

Figure 15. Drop 281 USNS Kane, deck launched. Profile of speed compared with dipole influence model.

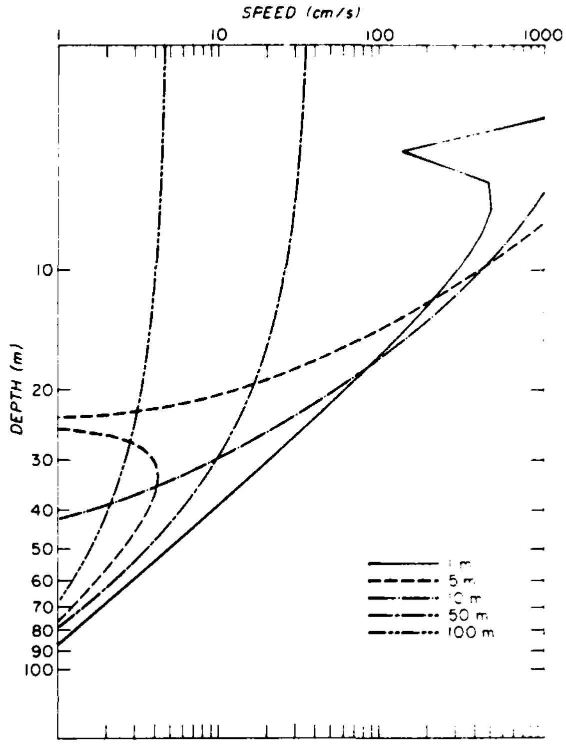

Figure 16. Dipole influence for a = 1, 5, 10, 50 and 100 m.

The model can be used to predict interference from the ship as a function of a, the distance of the release point from the ship. Figure 16 presents these results for a = 1, 5, 10, 50 and 100 m for p = 30.8 A-m. As expected, the level of interference and the depth of the notch change as a is increased. These calculations show that, even for a = 100 m, the interference is about 3-5 cm/s until a depth of 60-70 m. In order to limit the errors to <1 cm/s it seems that a ≃ 170 m is needed. Caution should be used in interpreting these results, since the model is rather crude and is based on only one calibration. On the other hand, p is reasonable in its strength, and the results are comparable to our rule of thumb.

Two examples, Figs. 17 and 18, of data and model fits are shown for drops launched from the starboard rail of the NOAA Oceanographer. In this case, a current dipole of 30.8 A-m was again used, but a = 2.5 m. Again the fit is reasonably good, and a predicted interference exceeds 1 cm/s until a depth of ~150 m. The larger depth scale for the Oceanographer versus the Kane is in the sense of their lengths, but this result may only be fortuitous, since vessel length does not enter the model.

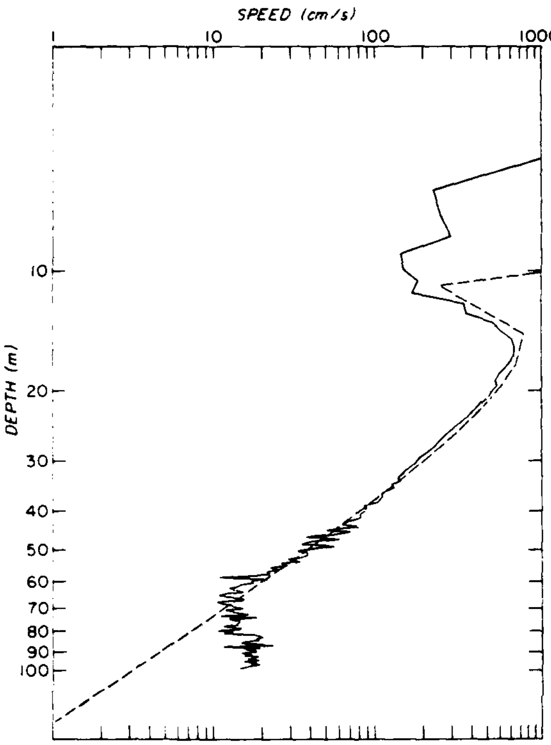

Figure 17. *Drop 438 NOAA Oceanographer, deck launched. Profile of speed compared with dipole model.*

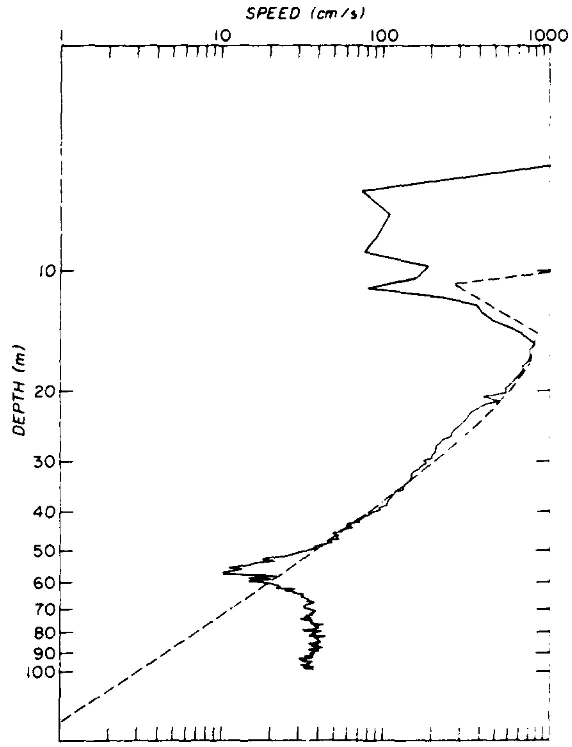

Figure 18. *Drop 396 NOAA Oceanographer, deck launched. Profile of speed compared with dipole model.*

Finally, the influence of the magnetic distortion of the Kane was examined. In Fig. 19, the magnitude of the coil area is shown for a sampling of differently launched profiles. The coil area is used as a measure of magnetic disturbance. It is also sensitive to tilt, which makes the interpretation of this signal somewhat ambiguous. Nonetheless, if the ship distorts the earth's magnetic field, then we expect the coil output to change with depth. The coil area is the variable to look at, since variations due to changing rotation frequency are removed. In Fig. 19 the profiles seem to converge to a similar value at about 30 m. Above this depth the area seems to be influenced by the vessel.

The final two figures, 20 and 21, show examples of simultaneous profiles from deck and remote launchers aboard the Kane. Here we see clear cases of the convergence of the area variable below 30 m. Since the compass signal does enter the electric field channel, it is important to avoid magnetic contamination.

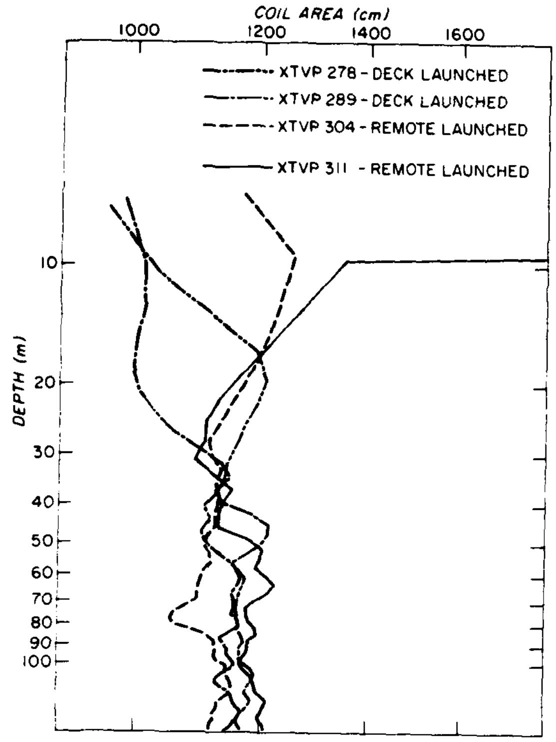

Figure 19.

Coil area profiles for variously launched probes from USNS Kane.

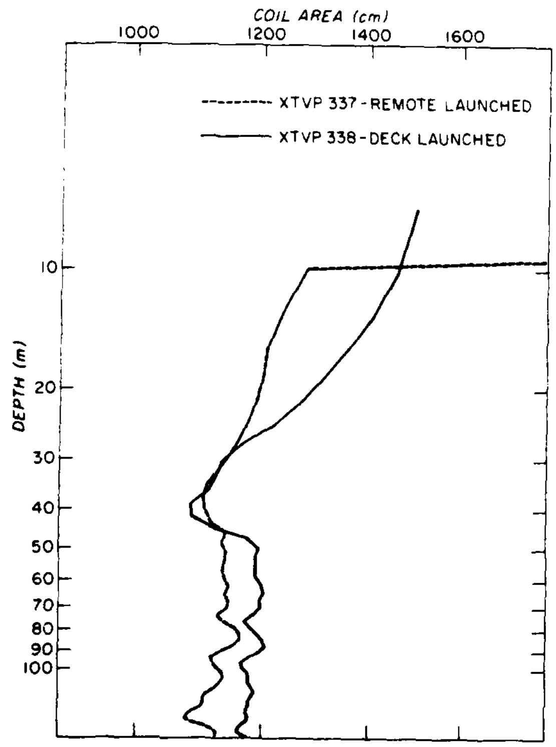

Figure 20. Simultaneous deck and remote launched profiles of coil area from USNS Kane.

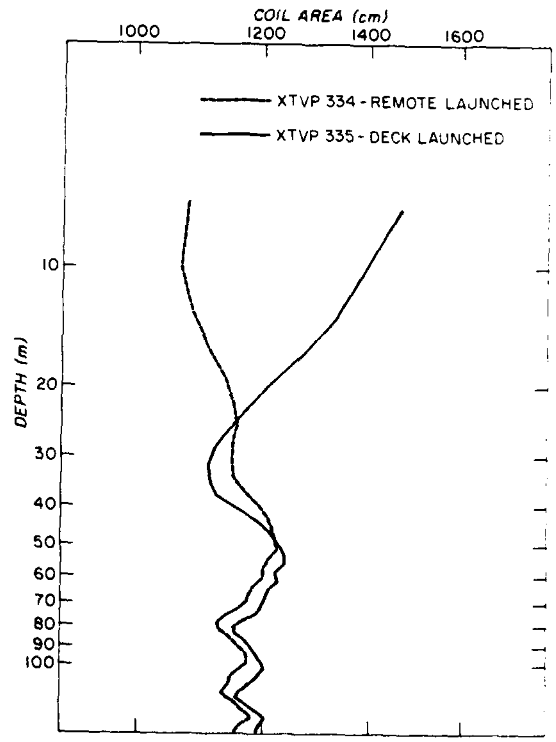

Figure 21. Simultaneous deck and remote launched profiles of coil area from USNS Kane.

The Kane profiles show a tendency for the coil area to be low around the vessel compared with that farther away. This suggests that near the ship the magnetic field is less.

On the basis of this analysis, it is recommended that probes be released 1-2 vessel lengths (100-200 m, depending on the ship) behind the vessel to reduce electric and magnetic influences to less than 1 cm/s. The analysis is subject to considerable error, since it is based on an extrapolation of near-ship observations. More profiles should be taken at distances of 1-50 m from the ships, or more detailed electric and magnetic measurements should be made. The latter does not require expenditure of XTVP probes. Also there may be a significant improvement achieved in the reduction of the electric influence if active cathodic protection (if used) is suspended during profiles. That is, p may be due to electric currents deliberately circulated to protect the propeller and shafts from corrosion. Suspension of this activity for brief periods would be beneficial to the data quality and not too detrimental to corrosion control.

The numerical calculations were carried out by John Litherland.

B. INFLUENCES OF SPATIAL AND TEMPORAL VARIATIONS OF THE GEOMAGNETIC FIELD

Spatial and temporal variations of the geomagnetic field can strongly influence the operation of the XTVP and interpretation of the measurements. The elements of the main, steady geomagnetic field determine the generation of the motionally induced electric currents. Regions of large and small geomagnetic components are shown in Fig. 22. Errors in the knowledge of these elements lead to errors in the interpretation of the measurements. An error in F_H tends to contribute an error to the north flow component, while F_z errors lead to scaling errors for both flow components. Variations of $\underset{\sim}{F}$ in space and time lead to the generation of $\underset{\sim}{J}^*$ electric currents.

Errors in estimating the magnetic field components arise mainly from magnetic anomalies of spatial scales smaller than detailed in the world charts (DMAHC magnetic field charts, #33 and 36). The magnitude of temporal variations is generally less than 1% of the steady field. However, these time variations generate induced electric currents which can be quite large compared with the motionally induced signals.

The main field, approximately that of a magnetic dipole aligned along the axis of rotation, has components

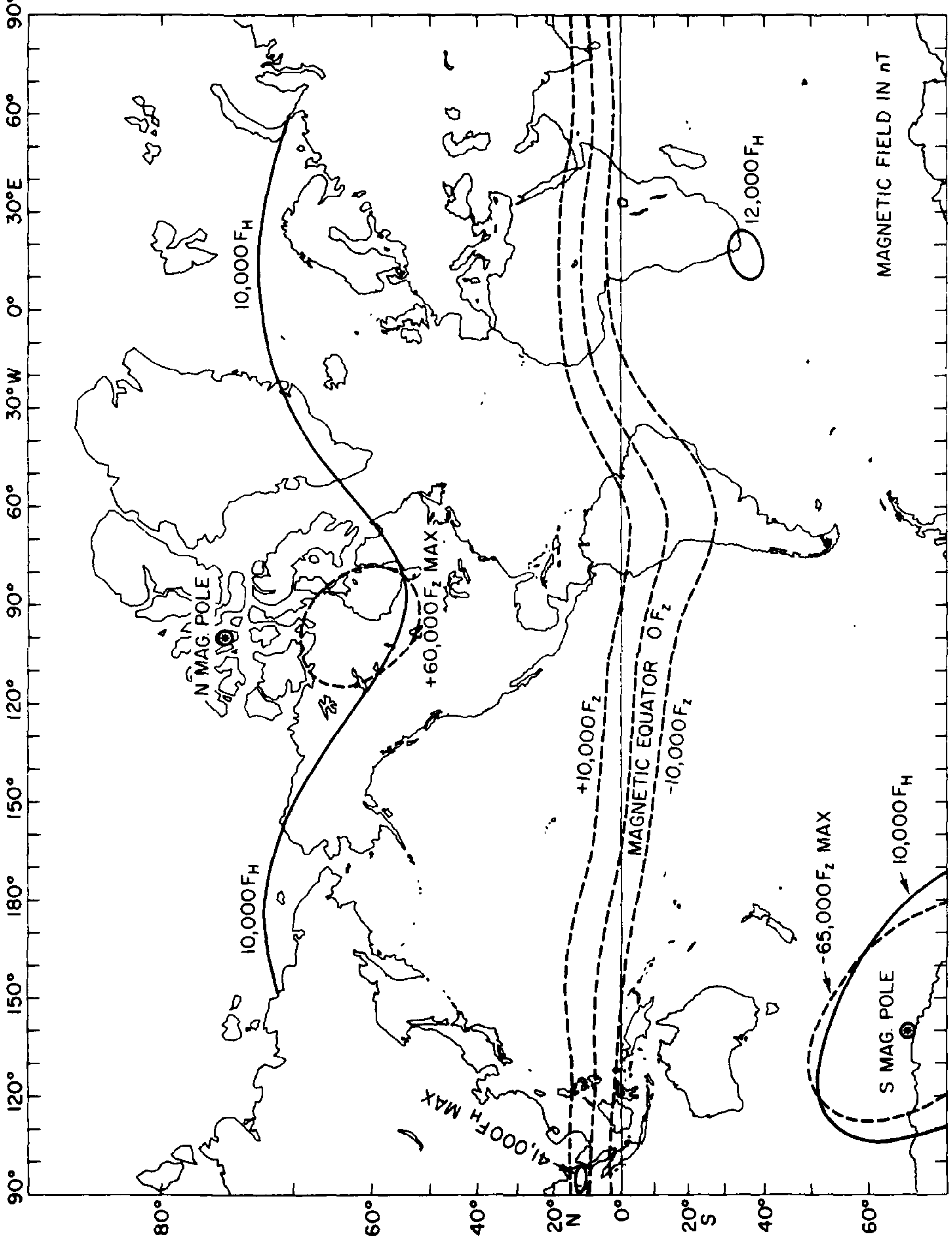

Figure 22. Locations of zones of small F_z (magnetic equator) and small F_H (magnetic poles).

$$F_H = \frac{M \cos \theta}{r^3}$$

and (42)

$$F_z = - \frac{2M \sin \theta}{r^3} ,$$

where $M = 8 \times 10^{15}$ tesla-m^3, θ is the latitude (positive to north) and r the geocentric radius.

The variations with depth are small: $(1\ \gamma = 10^{-9}$ teslas)

$$\frac{\partial F_H}{\partial z} \simeq - 1.4 \times 10^{-11} \cos\theta \text{ tesla/m}$$

$$\simeq - 1.4 \cos\theta\ \gamma/100 \text{ m} , \qquad (43)$$

$$\frac{\partial F_z}{\partial z} \simeq 2.8 \sin\theta\ \lambda/100 \text{ m} .$$

Within a 5 km deep ocean, the percentage changes to F_H and F_z are:

$$\frac{\Delta F_H}{F_H} \simeq \frac{\Delta F_z}{F_z} \simeq - 0.25\% . \qquad (44)$$

The horizontal variations are

$$\frac{1}{r} \frac{\partial F_H}{\partial \theta} = \frac{1}{2} F_z/r \simeq - 4\gamma/\text{km} ,$$

(45)

$$\frac{1}{r} \frac{\partial F_z}{\partial \theta} = - 2 F_H/r \simeq - 8\gamma/\text{km} .$$

An uncertainty in latitude, $\Delta\theta$, leads to

$$\begin{aligned} \frac{\Delta F_H}{F_H} &= -\,\Delta\theta \tan\theta \,, \\ \frac{\Delta F_z}{F_z} &= \Delta\theta \cot\theta \,. \end{aligned} \tag{46}$$

At mid-latitudes ($\theta \simeq 40°$), the errors are ~1-2% per degree of latitude. The world charts (#33 and 36) are contoured every 1000 γ for F_H and 2000 γ for F_z, and can be scaled to at least 100 γ. If the charts were accurate to 100 γ, then $2F_H/F_H \simeq 0.5\%$ and $\Delta F_z/F_z \simeq 0.25\%$. However, it is known that the world chart is not accurate to this extent everywhere.

Small-scale magnetic anomalies exist over many topographic features such as seamounts, islands and submarine ridges. For instance, a fine-scale aeromagnetic survey of Plantagenet Bank, 25 n.mi. SW of Bermuda (Young and Kantis, 1964), reveals that the undisturbed field is 4-6% different from the world chart. Over the Bank itself, the errors reach 10-15%. Vertical and horizontal field gradients are 100 times larger than over an undisturbed area.

The magnetic field generated by the motionally induced electric currents has components no larger than 0.25% of the main geomagnetic field.

Temporal variations of the geomagnetic field generate electric fields and currents in the ocean. These magnetotelluric fields depend on the frequency and structure of the source magnetic field and on the depth and electrical conductivity of the ocean crust and mantle.

Magnetotelluric currents represent one of the largest sources of error in the EM profiling method. These effects are generally not independently measured or easily inferred from land-based magnetic measurements.

Cox, Filloux and Larsen (1971) and Fonarev (1968) have provided estimates of the electric fields generated by geomagnetic variations. The magnetic variations are described by Chapman and Bartels (1940). Variations having periods longer than one day generate only weak electric fields (<<1 μV/m). Shorter period variations are responsible for significant electric induction. The major categories for the high-frequency variations are the solar-diurnal variations, bay-like disturbances, magnetic storms and short-period variations.

Solar-diurnal variations are always present, even on magnetically quiet days. These variations result in electric fields of the order of $3 \times 10^{-2} \mu V/m/\gamma$ in the open ocean. The maximum influence of these variations is given in Table 12 [Fonarev (1968)].

Bay-like disturbances derive their name from their appearance as bays or gulfs on magnetograms. These events provide mainly horizontal magnetic fields which decrease away from the auroral zone (70°). Frequencies from tens of minutes to a few hours are present. Bay disturbances occur 10 to 40 times per year with an amplitude of 40-100 γ. An estimate of the resulting induction can be derived for a plane wave impinging on the sea surface. Such a wave will be attenuated as it propagates into the sea due to the generation of electric currents with opposing magnetic fields. At any depth, the magnetic field is

$$\underset{\sim}{B}(z) = \underset{\sim}{B}_o e^{z/\delta} , \tag{47}$$

where $\underset{\sim}{B}_o$ is the surface value and δ is the skin depth. The skin depth is defined as

$$\delta = \left(\frac{2}{\mu\sigma\omega}\right)^{1/2} , \tag{48}$$

where the permeability $\mu = 4\pi \times 10^{-7}$ H/m, σ is the electrical conductivity and ω is the radian frequency of the wave.

The electric currents can be computed from Ampere's law:

$$\nabla \times \underset{\sim}{B} = \mu \underset{\sim}{J} . \tag{49}$$

The electric field due to the current density $\underset{\sim}{J}$ is $\underset{\sim}{J}/\sigma$. Hence

$$E = \frac{B_o}{\mu\sigma\delta} e^{z/\delta} . \tag{50}$$

Table 12. Magnetotelluric effects [after Fonarev (1968)]:
For solar-diurnal variations

Latitude	Activity	B,γ	E,μV/m	V,cm/s
<30°	Quiet	30-80	0.9-2.4	4.5-12
	Disturbed	60-100	1.8-3.0	9.0-15
30-60	Quiet	15-60	0.45-1.8	1.1-4.2
	Disturbed	25-110	0.75-3.3	1.9-8.2
>60°	Quiet	90-400	2.7-12	4.6-20
	Disturbed	50-460	1.5-14	2.5-22

For magnetic storm variations[1]

Latitude	Activity	B,γ	E,μV/m	V,cm/s
<30°	Weak	0-30	0-2	0-9
	Moderate	15-60	1-4	4-18
	Strong	30-90	2-5	9-26
30-60	Weak	40-120	2-7	6-17
	Moderate	70-300	4-16	10-44
	Strong	150-700	9-41	22-103
>60°	Weak	70-600	4-32	7-60
	Moderate	150-900	9-52	15-88
	Strong	900-1500	52-88	88-150

[1]For water depth of 5 km and σ = 2.7 S/m.

This expression is appropriate for an infinitely deep ocean or when $\delta < H$. The latter condition occurs for wave periods of 5 min or less. For longer periods, a more appropriate expression is:

$$E(\mu V/m) = \frac{\sqrt{5\rho_a}\, B(\gamma)}{\sqrt{T}} , \tag{51}$$

where ρ_a is the apparent resistivity (combination of ocean and mantle resistivities) in ohm-m and T is the wave period in seconds. According to Poehls and von Herzen (1976), ρ_a in the NW Atlantic is about 20 ohm-m. Hence,

$$E \sim \frac{10\ B(\gamma)}{\sqrt{T}} . \tag{52}$$

For a bay-like disturbance of 40 γ over a period of 3 hours,

$$E = 3.8\ \mu V/m , \tag{53}$$

leading to a velocity error of about 5 cm/s. Since the bay-like disturbances are of very large scale, it is possible to estimate the errors, perhaps even to correct the measurements, using land-based magnetic records.

Magnetic storms are more irregular than bay disturbances, often having rapid changes at the commencement over a few hours followed by a gradual recovery over tens of hours. The E/B ratios are the same as for the bay but the a amplitude of B can be much larger, particularly in the auroral zone. According to Fonarev (1968), magnetic storms are as frequent as 20-50 times per year during years of maximum solar activity while 3-5 times fewer in years of minimum activity. The peak-to-peak variations and the expected electric induction and velocity errors are listed in Table 12.

Except for the most rapid components of magnetic storms, bays and diurnal disturbances produce little depth-dependent electric variations. That is, the energetic, long-period disturbances induce mainly depth-uniform electric currents, and these do not contribute errors to XTVP

profiles. Short-period variations (periods less than 10 minutes) are weak and contribute little induced electric field except in polar regions.

According to Fig. 16 of Cox et al. (1971), the electric field has a variance of about 0.1 $(\mu V/m)^2$ in the frequency band from 0.1 to 12 c/h. Thus we might expect deviations between profiles spaced several hours apart of about 0.6 cm/s due to changes in the ambient electric field. Over a small frequency interval, say, 1 to 12 c/h, the variance is about 10^{-2} $(\mu V/m)^2$ yielding a standard deviation of 0.2 cm/s.

C. TILT EFFECTS IN XTVP DATA

The XTVP is designed to measure electric currents present in the sea induced by the motion of seawater through the earth's magnetic field. Drever and Sanford (1980) and Sanford et al. (1978) discuss the calculation of oceanic velocities from these electrical measurements, assuming that the instrument remains vertical. Small instrumental tilts, however, are produced by vertical shear. In this report the effect of these tilts on the computed velocity profile is investigated and an algorithm to correct for these effects is developed and tested.

1. Model of Tilt Effects

The XTVP measures the electric potential between a pair of electrodes on opposite sides of a rotating cylinder falling through the ocean. The measured potential is the sum of a potential $\Delta\phi_v$ due to induced electric currents $\underset{\sim}{J}$ and a potential $\Delta\phi_I$ due to the motion of the probe through the water. Both potentials are modified by the presence of the insulating probe within the conducting seawater.

The oceanic electric current density $\underset{\sim}{J}$ is assumed to be entirely horizontal, due to the large aspect ratio of oceanic currents. Let

$$\underset{\sim}{J}/\sigma = F_z(v\hat{\underset{\sim}{x}} - u\hat{\underset{\sim}{y}}) \quad , \tag{54}$$

where $\hat{\underset{\sim}{x}}$, $\hat{\underset{\sim}{y}}$, $\hat{\underset{\sim}{z}}$ are unit vectors in an earth fixed coordinate system (Fig. 23). F_z is the vertical component of the earth's magnetic field and u,v are the components of the purely horizontal current relative to the unknown electrical offsets u*,v* (Sanford, 1971). This electrical current results in a potential drop

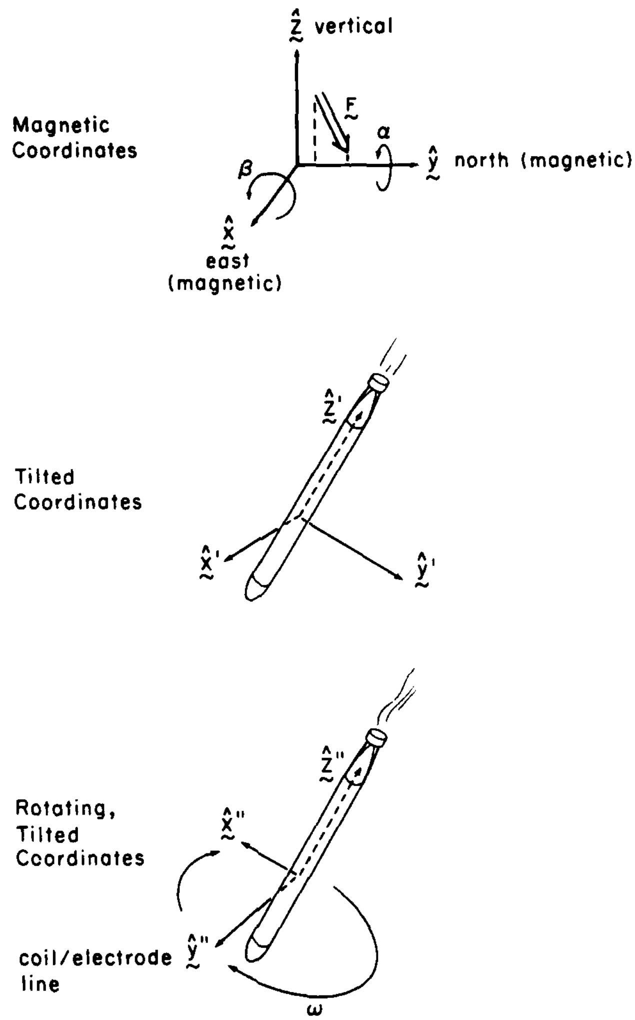

Figure 23. Coordinate systems used in the analysis. ($\hat{x}$, $\hat{y}$, $\hat{z}$) is an earth fixed system, with $\hat{y}$ pointing north (magnetic). The magnetic field has no east component, and the oceanic velocities have no z component. ($\hat{x}'$, $\hat{y}'$, $\hat{z}'$) is a coordinate system fixed with the probe, but not rotating, and is rotated by angles α and β with respect to ($\hat{x}$, $\hat{y}$, $\hat{z}$). ($\hat{x}''$, $\hat{y}''$, $\hat{z}''$) is fixed with the probe and rotating with it so that $\hat{y}''$ is along the electrode/coil line. Table 13 gives the rotation matrices between these systems.

Table 13. Rotation matrices.

R_α: y axis rotation by α (ccw)

$$\begin{matrix} \cos\alpha & 0 & \sin\alpha \\ 0 & 1 & 0 \\ -\sin\alpha & 0 & \cos\alpha \end{matrix}$$

R_β: x axis rotation by β (ccw)

$$\begin{matrix} 1 & 0 & 0 \\ 0 & \cos\beta & \sin\beta \\ 0 & -\sin\beta & \cos\beta \end{matrix}$$

R_ω: z axis rotation by ω (cw)

$$\begin{matrix} \cos\omega t & -\sin\omega t & 0 \\ \sin\omega t & \cos\omega t & 0 \\ 0 & 0 & 1 \end{matrix}$$

<u>Probe coordinates</u>:

$$\begin{matrix} \hat{\underset{\sim}{x}}' \\ \hat{\underset{\sim}{y}}' \\ \hat{\underset{\sim}{z}}' \end{matrix} = R_\beta \; R_\alpha \begin{matrix} \hat{\underset{\sim}{x}} \\ \hat{\underset{\sim}{y}} \\ \hat{\underset{\sim}{z}} \end{matrix}$$

$$R_\beta \; R_\alpha = \begin{matrix} \cos\alpha & 0 & \sin\alpha \\ -\sin\alpha \sin\beta & \cos\beta & \cos\alpha \sin\beta \\ -\sin\alpha \cos\beta & -\sin\beta & \cos\alpha \cos\beta \end{matrix}$$

<u>Rotating probe coordinates</u>:

$$\begin{matrix} \hat{x}'' \\ \hat{y}'' \\ \hat{z}'' \end{matrix} = R_\omega \; R_\beta \; R_\alpha \begin{matrix} \hat{x} \\ \hat{y} \\ \hat{z} \end{matrix}$$

$$R_\omega \; R_\beta \; R_\alpha = \begin{matrix} \cos\alpha \cos\omega t & -\cos\beta \sin\omega t & \sin\alpha \cos\omega t \\ +\sin\alpha \sin\beta \sin\omega t & & -\cos\alpha \sin\beta \sin\omega t \\ \cos\alpha \sin\omega t & \cos\beta \cos\omega t & \sin\alpha \sin\omega t \\ -\sin\alpha \sin\beta \cos\omega t & & +\cos\alpha \sin\beta \cos\omega t \\ -\sin\alpha \cos\beta & -\sin\beta & \cos\alpha \cos\beta \end{matrix}$$

$$\Delta\phi_V = -(1+C_1)\ell\hat{\underset{\sim}{y}}''\cdot\underset{\sim}{J}/\sigma \tag{55}$$

across the probe electrodes, where ℓ is the electrode separation, $\hat{\underset{\sim}{y}}''$ is the orientation of the electrode line, and $C_1 \simeq 0.9$ gives the magnification of the potential difference due to the presence of the probe. Because the electric current density must increase as the current is diverted by the probe, the voltage drop increases by the factor $1 + C_1$.

The potential $\Delta\phi_I$ induced by the probe motion relative to the water is best calculated in a nonrotating coordinate system oriented with the probe. Let $\hat{\underset{\sim}{z}}'$ be along the probe axis. The fixed system $\hat{\underset{\sim}{x}}$, $\hat{\underset{\sim}{y}}$, $\hat{\underset{\sim}{z}}$ can be transformed into the probe system $\hat{\underset{\sim}{x}}'$, $\hat{\underset{\sim}{y}}'$, $\hat{\underset{\sim}{z}}'$ by a rotation of α about $\hat{\underset{\sim}{y}}$ followed by an x-axis rotation of β (Table 13, Fig. 23). In this coordinate system the induced potential is given by (Sanford et al., 1978, Equation A12)

$$\begin{aligned}\Delta\phi_I = {} & (1+C_2)\ell\hat{\underset{\sim}{y}}''\cdot(F_{y'}\hat{\underset{\sim}{x}}' - F_{x'}\hat{\underset{\sim}{y}}')W' \\ & + (1+C_3)\ell''\cdot(U'\hat{\underset{\sim}{y}}' - V'\hat{\underset{\sim}{x}}')F_{z'} \ ,\end{aligned} \tag{56}$$

where W', U', and V' are the probe velocities relative to the water in the nonrotating probe coordinate system, and $\hat{\underset{\sim}{y}}''$ is the orientation of the electrode line. Motion of the probe relative to the surrounding water results in two signals: induction by the relative motion of the probe itself and by the perturbation flow around the probe. These two signals may nearly cancel; the estimated values of C_2 and C_3 are -0.1 and -0.8 respectively.

The east and north components of velocity are determined relative to the voltage induced in a coil (the compass coil) coaxial with the electrode line. For technical reasons, a fraction c of the coil signal is also added to the measured electrode signal. Assuming the coil to have a total area A_o, the potential induced in the coil by the probe's rotation is

$$\Delta\phi_c = \frac{d}{dt}(\underset{\sim}{F}\cdot A_o\hat{\underset{\sim}{y}}'') = \omega A_o\underset{\sim}{F}\cdot\hat{\underset{\sim}{x}}'' \ , \tag{57}$$

assuming

$$\frac{d\alpha}{dt}, \frac{d\beta}{dt} \ll \omega \ .$$

Using the rotation operators shown in Table 13 and Eqs. (55), (56) and (57), the following expressions can be derived to lowest order in α and β:

$$\Delta\phi_v = (1+C_1)\ell F_z[u \cos\omega t - v \sin\omega t] , \tag{58}$$

$$\Delta\phi_I = (1+C_2)\ell W' [(F_y+\beta F_z)\sin\omega t - \alpha F_z \cos\omega t] + (1+C_3)\ell(F_z - \beta F_y)[U'\cos\omega t - V'\sin\omega t] , \tag{59}$$

$$\Delta\phi_c = - F_y \omega A_o [(1+ \frac{F_z}{F_y} \beta)\sin\omega t - \alpha \frac{F_z}{F_y} \cos\omega t] . \tag{60}$$

The XTVP electrode signal transmitted up the wire is

$$\Delta\phi = \Delta\phi_v + \Delta\phi_I + c\Delta\phi_c . \tag{61}$$

This is then demodulated with the coil signal to produce in-phase (north) and quadrature (east) signals. If $\alpha = \beta = U' = V' = 0$, the coil signal is proportional to $I = \sin\omega t$, and is in quadrature with $Q = \cos\omega t$. The demodulation yields

north:

$$\Delta\phi_n = \overline{I\Delta\phi} = -v(1+C_1)\ell F_z + [(1+C_2)\ell W' + c\omega A_o]F_y , \tag{62}$$

east:

$$\Delta\phi_e = \overline{Q\Delta\phi} = u(1+C_1)\ell F_z , \tag{63}$$

where the overbar denotes a time average. Equation (62) is identical to Eq. (4) of Drever and Sanford (1980). If W' is known, the oceanic velocities u and v can be determined.

The direction of north is defined by the phase of the coil signal. For a vertical probe, the coil signal passes through zero when the coil ($\hat{\underset{\sim}{y}}$") points north. If the probe is not vertical, an east-west tilt results in a phase shift of the coil signal so that this zero crossing no longer gives the same direction. The demodulation signals using (60) are now

$$I = \sin\omega t - \alpha \frac{F_z}{F_y} \cos\omega t \ , \tag{64}$$

$$Q = \cos\omega t + \alpha \frac{F_z}{F_y} \sin\omega t \ , \tag{65}$$

and the demodulated signals are

north:

$$\begin{aligned} \Delta\phi_n = &- (1+C_1)\ell F_z(v + \alpha \frac{F_z}{F_y} u) \\ &+ F_y(1+\beta F_z/F_y)[(1+C_2)\ell W' - c\omega A_o] \\ &- (1+C_3)\ell F_z(1-\beta F_y/F_z)(V' + \alpha \frac{F_z}{F_y} U') \ , \end{aligned} \tag{66}$$

east:

$$\begin{aligned} \Delta\phi_e = &(1+C_1)\ell F_z \ [u - \alpha \frac{F_z}{F_y} v] \\ &+ (1+C_3)\ell F_z(1- \frac{\beta F_y}{F_z})(U' - \alpha \frac{F_z}{F_y} V') \ . \end{aligned} \tag{67}$$

Equations (66) and (67) give the demodulated potential difference for a tipped probe with velocities U', V' and W' relative to the water.

Since the probe is a stable streamlined body, it will be assumed to fall along its length, so that $U' = V' = 0$. There is no direct verification of this assumption. However, since $(1+C_3)/(1+C_1) \simeq 0.1$, the measured potentials are much more sensitive to oceanic velocities (u,v) than probe velocities (U',V').

The probe tilt is seen to have two major effects. An east-west tilt ($\alpha \neq 0$) changes the measured phase of the coil signal and therefore mixes east and north contributions. This is seen in the first and last terms of (66) and (67). If α is small, this effect is small. A north-south tilt changes the magnitude of the magnetic field parallel to the probe (F_z'), leading to a change in both the coil and W' induced signals. This can be seen in the second term of (66).

The effect of these tilts is seen in a different way if the calculation is done entirely in the fixed coordinate frame. Suppose the probe is falling with velocity components U, V and W in a stationary ocean (i.e., $\underset{\sim}{J} = 0$); the induced potential is given by

$$\Delta\phi_I = [F_y W \underset{\sim}{\hat{x}} + F_z(U\underset{\sim}{\hat{y}} - V\underset{\sim}{\hat{x}})] \cdot \underset{\sim}{\hat{y}}'' \ , \tag{68}$$

where we take $C_1 = C_2 = C_3 = 0$ for simplicity. Since the probe is tilted and falling along its length, $U \simeq \alpha W$ and $V \simeq \beta W$. Neglecting, for the moment, the small phase shift caused by α,

$$\underset{\sim}{\hat{y}}'' = \underset{\sim}{\hat{x}} \sin\omega t + \underset{\sim}{\hat{y}} \cos\omega t \ , \tag{69}$$

and the measured signals are

north:

$$\Delta\phi_n = \beta W F_z + W F_y = F_y(1 + \beta\, F_z/F_y)W \ , \tag{70}$$

east:

$$\Delta\phi_e = - \alpha\, W F_z \ . \tag{71}$$

The tilt causes the probe to move horizontally relative to the water; the probe measures an induced potential resulting from this motion. The resulting in-phase signal $\beta W F_z$ in (70) is clearly present in the second term of (66). The corresponding quadrature signal $-\alpha W F_z$, however, is not present in (67). It is canceled by the east-west tip term neglected in (70) and (71). As discussed above, an east-west tip α results in a phase shift in the coil signal. This mixes the east and north potentials. The north potential is dominated not by the north velocity potential, but by induced potential due to W. The primary effect of the coil phase shift is thus to mix some of this W induced potential into the east potential. The additional east potential is of magnitude $\alpha W F_z$ and exactly cancels the α induced potential in (71). Switching to probe coordinates, this clearly must be true, since the signal induced by W' is in phase with the coil, and cannot appear in the east signal. Thus, except for the small amount of east-north mixing, there is no effect of tilt in the east velocity component, to first order, if the probe falls along its length.

2. Processing Changes

The present XTVP processing computes a north velocity $\hat{v}$ using

$$\hat{v} = - [\Delta\phi_n - (1+C_2)\ell F_y {*}_{*} - c\,\Delta\phi_c]/(1+C_1)\ell F_z \ , \tag{72}$$

where W_e is the estimated fall rate and $\Delta\phi_c$ is calculated from the probe rotation rate. Using (60), (64) and (66) with U' = V' = 0, the computed velocity will be

$$\hat{v} = (v + \alpha \frac{F_z}{F_y} u) + \frac{F_y}{F_z} \frac{(1+C_2)}{(1+C_1)} (W_e - W') - \beta \frac{(1 + C_2)}{(1 + C_1)} W' \ . \tag{73}$$

The computed north velocity contains three errors: a mixing of u with v due to east-west tip (α), an error due to the incorrect estimation of W_e, and an error due to north-south tilt (β). Since $W' \simeq 450$ cm/s >>u, the last term is dominant. A north-south tip of 1° will lead to an error of 4 cm/s.

It is possible to correct for the β tilt. Using (60), the magnitude of the coil signal is

$$\Delta\phi_c = \omega F_y A_o (1 + \frac{F_z}{F_y}\beta) \; . \tag{74}$$

The effective area of the coil is

$$A = \frac{\Delta\phi_c}{\omega F_y} = A_o(1 + \frac{F_z}{F_y}\beta) \; , \tag{75}$$

which to first order in α and β is a function only of the north-south tilt. The third term in (73) can be estimated using

$$-\beta \frac{(1 + C_2)}{(1 + C_1)} W' \approx - (\frac{A}{A_o} - 1) \frac{F_y}{F_z} \frac{(1 + C_2)}{(1 + C_1)} W_e \; , \tag{76}$$

and removed from the estimate of v using

$$\hat{v} = -[\Delta\phi_n - \frac{A}{A_o}(1 + C_2)F_y W_e - c\Delta\phi_c]/(1 + C_1)F_z \; . \tag{77}$$

In practice, A_o is estimated from the vertical mean of A, since the fluctuations in A occur on a relatively short vertical scale.

3. Comparison of Tilt-Corrected and Uncorrected Profiles

Figure 24 shows a typical XTVP profile of east and north velocity and area as defined by (75). Interpreting the area fluctuations as tilt fluctuations, the probe is seen to tilt only a few degrees, north-south. These small tilts are sufficient, however, to significantly affect the computed north velocity. Notice the difference between the velocity computed using (72) (light line) and (77) (heavy line, tilt corrected). The north velocity is most affected on the 10-50 m scale, where the area, or tilt, fluctuations are concentrated. Note that the corrected profile shows less correlation with the area than the uncorrected profile, and that the tilt correction primarily affects the amplitude, not the phase, of the computed profile.

The effect of the tilt correction on different vertical scales is more clearly seen in Fig. 25. The average autospectra of east and north

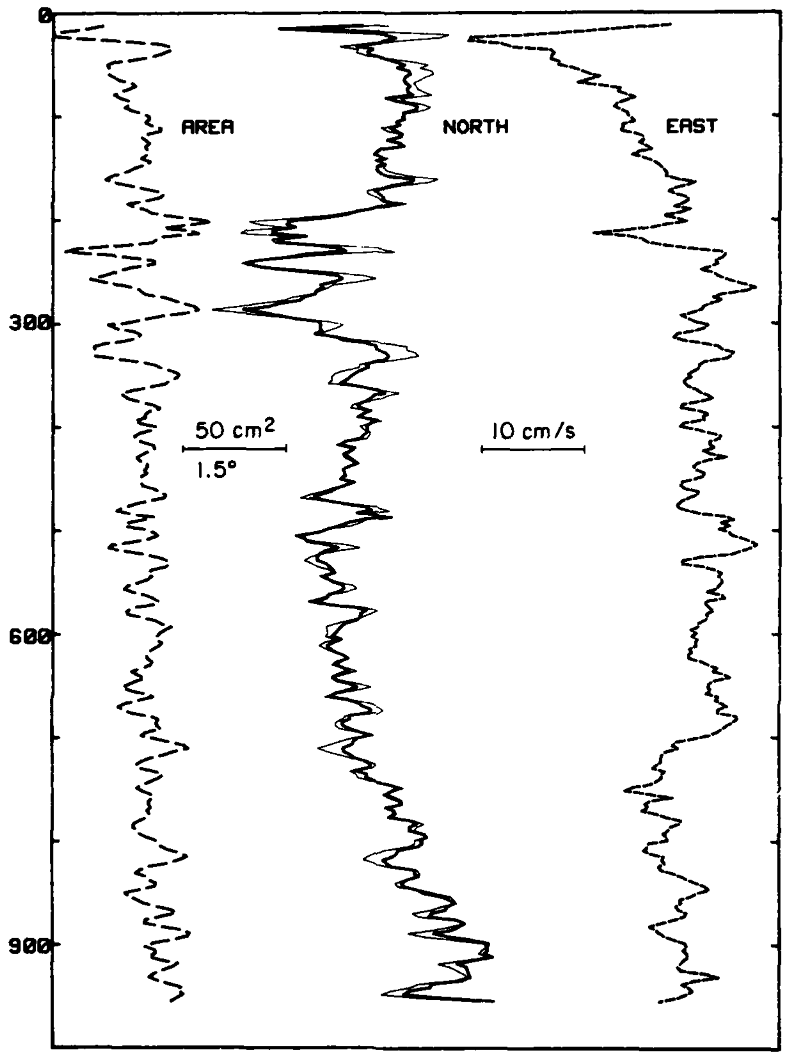

Figure 24. A low noise XTVP profile (AUTEC 176) of east and north relative velocity, and effective coil area (75). North is computed both by (72) (uncorrected, light line) and by (77) (corrected, heavy line). Area is also interpreted as north-south tilt.

from 64 XTVP profiles are shown with the north velocity computed using both (72) (light line) and (77) (heavy line). The uncorrected data show more energy in north than east at scales smaller than 300 m, while the tilt corrected data show the same energy in east and north.

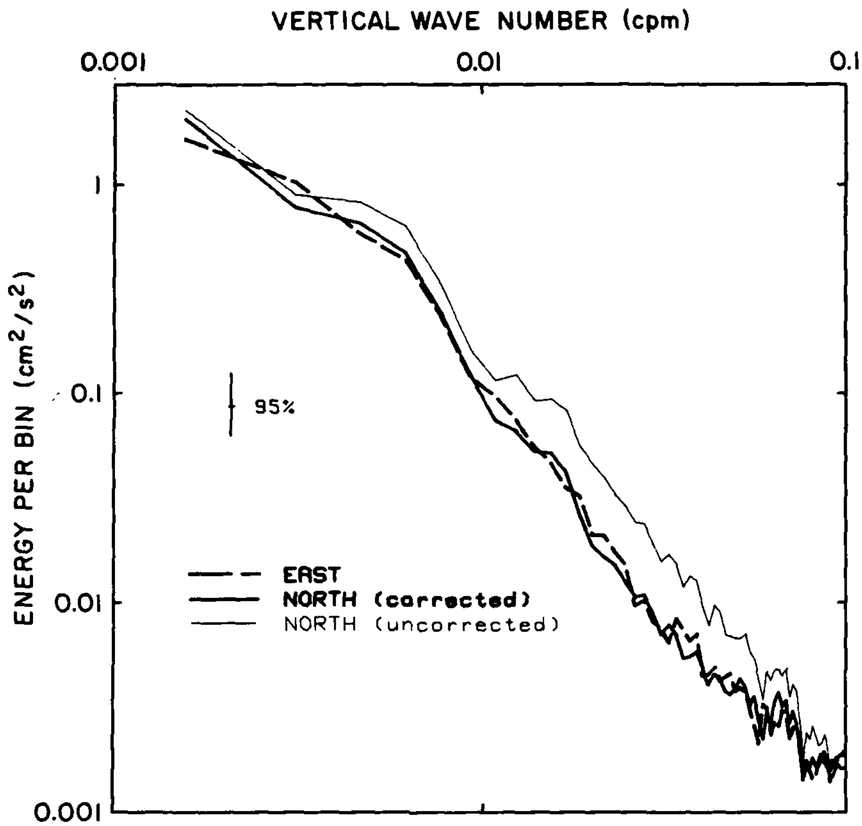

Figure 25. Average autospectra from 64 XTVP profiles taken during the USNS Kane *cruise. Both tilt-corrected by (77) and uncorrected by (72) north spectra are shown. The 95% confidence interval was computed using 64 EDOF. The wavenumber bin is 1/640 cpm.*

4. Comparison with Other Measurements

The differences between the corrected and uncorrected profiles occur primarily on vertical scales where internal wave fluctuations are dominant. Current meter measurements in the open ocean usually show an isotropic internal wave field with the same amount of energy in east and north (Wunsch, 1976). The corrected XTVP profiles, which show equal energy in east and north, agree with these current meter data, while the uncorrected data profiles do not.

Simultaneous velocity profiles using two different profilers are an excellent test of both instruments. Two such comparisons are discussed below, an XTVP comparison with TOPS (Hayes, 1981; data courtesy of Dr. S. Hayes NOAA/PMEL), a profiler expected to be most accurate at 1-50 m scales, and a comparison with acoustically tracked floats (Wenstrand, 1979; data courtesy of Dr. D. Wenstrand APL/JHU), which are expected to be most accurate at scales greater than 50 m.

Figure 26 compares the data obtained from nearly simultaneous drops of an XTVP and TOPS, a free-fall velocity profiler that measures its own velocity, relative to the ocean, using a nose mounted acoustic current meter. A model of the body dynamics is used to compute the large scale velocity profile from these measurements. Figure 26 compares the autospectra from the uncorrected XTVP data and TOPS. The east spectra are

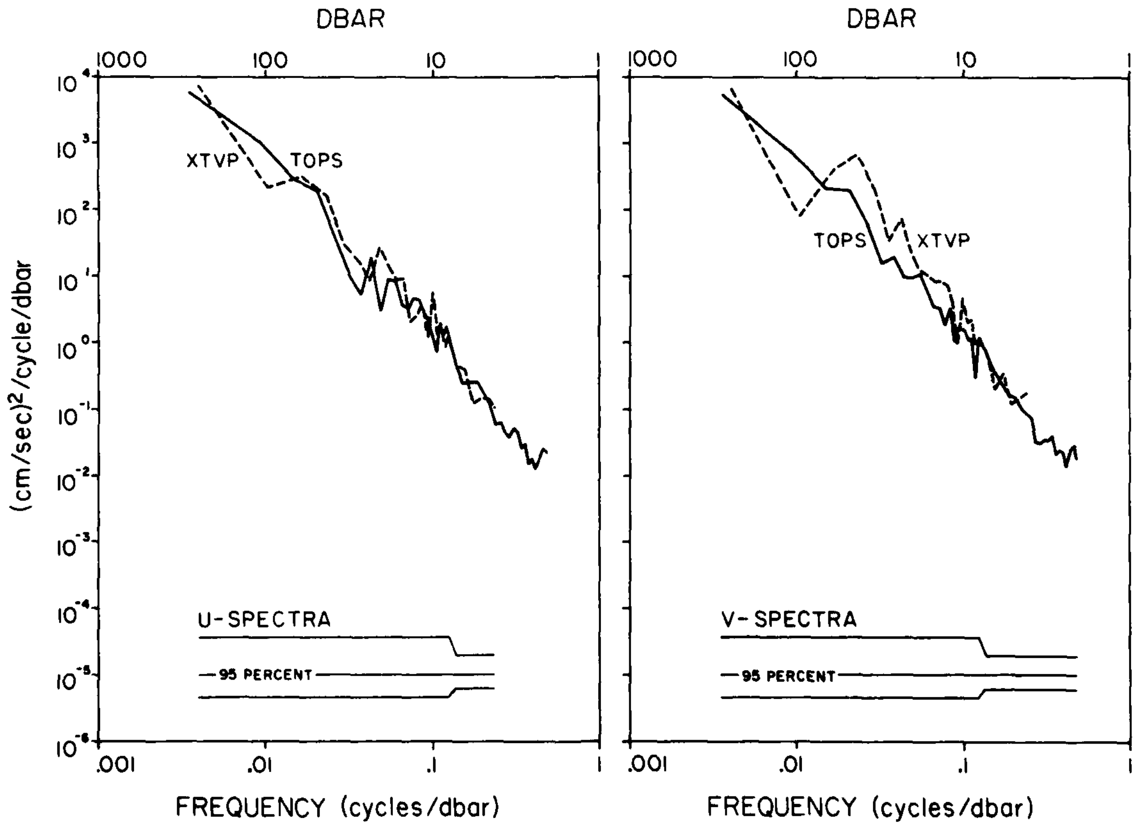

Figure 26. Autospectra from TOPS/XTVP intercomparison. XTVP data are not tilt corrected. (Figure courtesy Dr. S. Hayes, NOAA/PMEL)

quite similar. The north spectra, however, show more energy in the XTVP profile at scales smaller than 100 m, just as in Fig. 25. This again suggests that the XTVP north velocity must be corrected for north-south tilt. Figure 27 compares the TOPS and XTVP profiles. If a slowly increasing depth offset in one of the profiles is recognized, the correspondence between the two profiles, especially on a feature for feature basis, is excellent, even with the uncorrected XTVP data.

Figure 28 shows a comparison between simultaneous XTVP and acoustically tracked dropsonde data. Sanford et al. (1981) discuss this intercomparison in more detail. Figure 28 compares a typical acoustic profile with an exceptionally quiet (for this data set) XTVP, processed both by (72) (uncorrected) and (77) (corrected). All three profiles have zero vertical mean; no other adjustments have been made. The correspondence between the acoustic and the corrected XTVP profiles is excellent. The uncorrected XTVP north profile fits the acoustic profile much less accurately than the corrected profile.

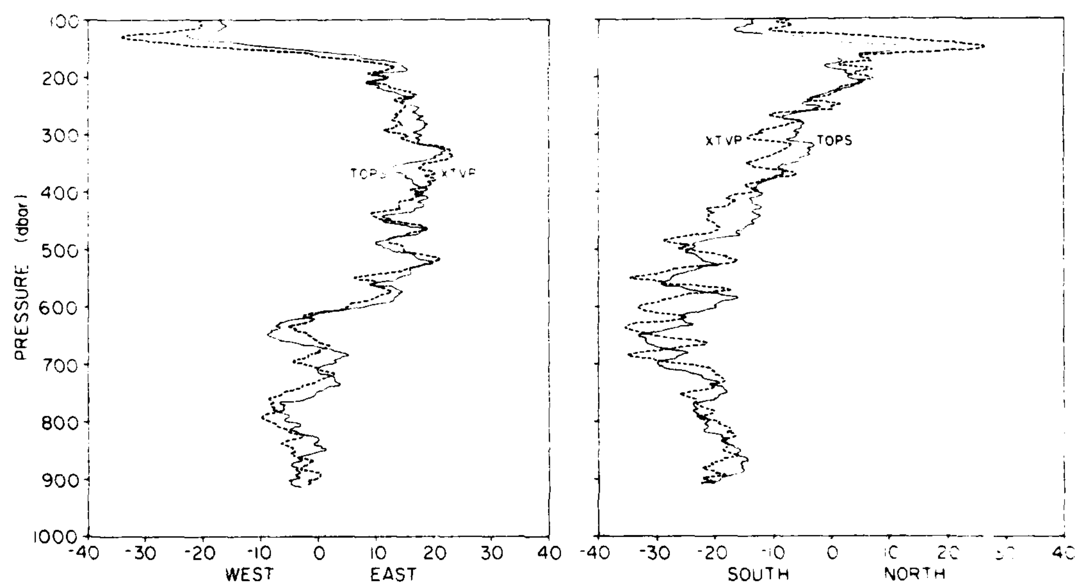

Figure 27. Velocity profiles from TOPS/XTVP intercomparison. (Figure courtesy of Dr. S. Hayes NOAA/PMEL)

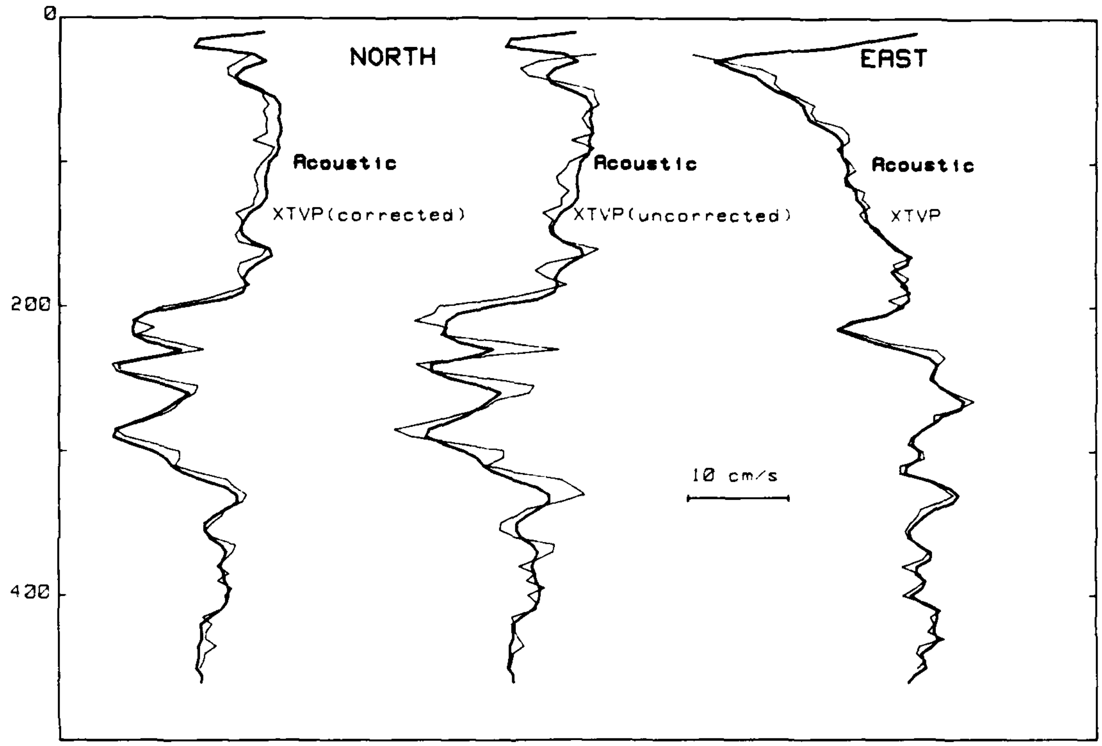

Figure 28. Comparison of nearly simultaneous XTVP (176) and acoustic tracked float (#7) velocity profiles. Both tilt-corrected by (77) and uncorrected (72) north XTVP profiles are shown. All profiles have zero vertical mean; otherwise not adjusted.

5. XTVP Error Analysis

The results of the acoustic dropsonde/XTVP intercomparison will be used to estimate the errors in the XTVP measurement. Each intercomparison set consists of an acoustic up and down profile, and several XTVP profiles taken during the acoustic profile. Three intercomparison sets are used below. In addition, simultaneous acoustic profiles using two different floats were taken.

Table 14 lists the rms differences between the various profiles averaged over all intercomparisons. Each profile is divided into two, 100-m sections (150-250 m, 250-350 m) and each pair of profiles is shifted vertically up to ±8 m so that a maximum correlation occurs. This allows for some depth error in the XTVP.

Table 14. The rms difference between adjusted profiles (cm/s).

	East	North	
Simultaneous acoustic profiles[1]	0.77	0.61	
Acoustic up/down pairs[2]	1.23	1.48	
		Tilt Corrected North	Uncorrected North
XTVP nearly simultaneous[3]	1.33	1.65	1.73
XTVP pairs within intercomparison[4]	1.33	1.55	1.78
XTVP/acoustic pairs[5]	1.19	1.38	2.06

[1] AUTEC profiles 8 and 9, 10 and 11, down profiles only. Time differences less than 5 minutes.

[2] AUTEC profiles 8, 9, 10, 11.

[3] All next neighbor pairs in sets (160-163), (165-169). Time differences less than 10 minutes.

[4] All pairs in sets (160-163), (165-169), (176, 179)

[5] All XTVP/acoustic pairs in sets (#4, 160-163), (#5, 165-169), (#7, 176, 179), where #4, #5, and #7 are AUTEC acoustic profiles.

For either acoustic velocity component A, let

$$A = O_A + \varepsilon_A \; , \tag{78}$$

where O_A is the oceanic velocity field measured by a noiseless acoustic profiler and ε_A is a random error. From simultaneous profiles, ε_A can be estimated with

$$\overline{(A_1 - A_2)^2} = 2\varepsilon_A^2 \; . \tag{79}$$

Using the statistics shown in Table 14, ε_A = 0.6 to 0.7 cm/s. The difference between the up and down acoustic profiles can be used to estimate the change in the oceanic velocity field during the profile:

$$\overline{(A_U - A_D)^2} = \overline{(O_{AU} - O_{AD})^2} + 2\varepsilon_A^2 . \tag{80}$$

A value of 0.5 cm/s is estimated.

Similarly, if either XTVP velocity component is given by

$$X = O_X + \varepsilon_X , \tag{81}$$

simultaneous XTVP profiles can be used to estimate ε_X,

$$\overline{(X_i - X_{i+1})^2} = 2\varepsilon_X^2 , \tag{82}$$

and the entire set of XTVP intercomparison profiles gives an estimate of the oceanic change during the experiment:

$$\overline{(X_1 - X_2)^2} = \overline{(O_{X_1} - O_{X_2})^2} + 2\varepsilon_X^2 . \tag{83}$$

Sufficient XTVP profiles simultaneous with the acoustic drops do not exist. The acoustic and XTVP error estimates have thus been made using data taken at different times on the same day. Table 14 shows no significant difference between the XTVP rms errors computed for nearly simultaneous profiles as in (82) or using all the profiles in each intercomparison set.

$$\overline{(O_{X_1} - O_{X_2})^2}$$

will thus be taken as zero. Some oceanic change is certainly present, but for the small number of profiles used here, it cannot be resolved.

Systematic differences may exist between the acoustic and XTVP velocity profiles. These can be computed from the XTVP/acoustic statistics:

$$\overline{(X - A)^2} = \overline{(O_X - O_A)^2} + \varepsilon_X^2 + \varepsilon_A^2 \ . \qquad (84)$$

Assuming that there is no temporal change in the ocean during the intercomparison, an upper limit for

$$\overline{(O_X - O_A)^2}^{\,1/2}$$

of 0.5 cm/s for the east or tilt corrected north is computed. Notice that the uncorrected north velocity shows a much larger systematic error of 1.6 cm/s. If some oceanic change is allowed, the calculated systematic error becomes smaller.

The XTVP errors are summarized in Table 15. The systematic velocity errors are significantly less than 1 cm/s, and the random velocity errors are about 1 cm/s. The XTVP's used in this intercomparison were early models, and showed a considerably higher noise level than more recently manufactured probes. The value of ε_X computed here certainly overestimates the random noise in more recent probes, probably by a factor of 2 or more.

6. Conclusions

The above analysis clearly shows the significance of small north-south tilts in affecting the measured XTVP north velocities. The velocity errors due to these tilts can be removed if the XTVP is assumed to fall along its length when tilted. An analysis of the AUTEC XTVP intercomparison with acoustically tracked floats shows that the tilt errors can be removed and an accurate velocity profile constructed.

This analysis reveals systematic differences of approximately 0.5 cm/s rms between the acoustic and XTVP profiles. The XTVP random error is estimated at 1 cm/s rms for this set of probes. The more recently manufactured probes have less random error.

Table 15. Error analysis results (cm/s).

	East	North
Acoustic random error ε_A	0.54	0.43
Acoustically measured oceanic change during up/down profiles $\overline{(O_{AU} - O_{AD})^2}^{1/2}$	0.45	0.47

	East	North Tilt Corrected	North Uncorrected
XTVP random error ε_X	0.94	1.1	1.25
XTVP/acoustic systematic error $\overline{(O_X - O_A)^2}^{1/2}$ upper bound	0.49	0.51	1.58

D. Surface Wave Interference

Surface waves produce strong surface enhanced velocities and electric currents. Typical particle velocities are about 100 cm/s, a large value compared with typical low frequency flows. Moreover, since the frequency is large, about 1 s^{-1}, the probe will see a time varying signal as it falls. The wave signal will appear as a vertical shear of wavelength equal to the probe's fall speed times the wave period. For a 6 s wave and a 4.5 m/s fall rate, the wavelength is 27 m.

The vertical attenuation of a surface wave depends on its horizontal wavenumber (k) which is ω^2/g, where ω is its frequency and g is gravity. For a 6 s period wave the wavelength is about 60 m. The velocity decreases as e^{kz}, which is $e^{-2\pi}$ or 0.002 at z = -60 m. Thus, caution must be exercised in the interpretation of velocity shear in the upper 50 m under typical ocean surface wave conditions.

E. Sensitivity Analysis

The rms error of the velocity estimates U' and V' is determined numerically using randomly determined probe tilts α and β, probe gains and probe component values. The digital receiver outputs I and Q are generated given U and V using deviated gains. U' and V' are then estimated from I and Q using nominal gains and component values.

The square root of the average variance of the velocity errors for 25 U and V combinations is found for 20 pseudoprobes. This is listed in Table 16 as the U and V rms error.

Table 16.

U,V rms error as a function of gain tolerances

U,V velocity range (±cm/s)	α,β tilt range (±°)	Probe gain tolerances (±°)	Probe phase tolerances (±°)	V/F converter tolerances (±°)	U,V rms error (cm/s)
20	1	0	0	0	0.3
20	1	1	1	1	0.4
40	0	0	0	0	
40	2	0	0	0	1.0
40	2	1	1	1	1.1

U,V rms error as a function of component tolerances

U,V velocity range (±cm/s)	α,β tilt range (±°)	Resistor tolerances (±%)	Resistor tolerances (±%)	V/F converter tolerances (±°)	U,V rms error (cm/s)
20	1	0.1	10	1	0.3
20	1	1	10	1	0.4
20	1	1	10	5	0.5
40	2	0.1	10	1	1.1
40	2	1	10	1	1.1
40	2	1	10	5	1.3
40	2	1	10	10	2.0
40	2	5	20	10	2.1

Typical ranges of U, V and tilt were used. The rms error scales linearly with U,V ranges and also increases with tilt. As the velocity range increases one would expect larger tilts and thus a more than proportional increase in error. Even with a perfectly known probe calibration, one should expect a 1.1 cm/s rms error over ±40 cm/s range with ±2° tilts.

Present resistor tolerances are 0.1%, but 1% would be sufficient (except for common mode rejection). The voltage to frequency (V/F) converters should be within 5% for less than 1.5 cm/s rms error.

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APPENDIX A
Program Listings and Sample Runs

Listing of Program DXGET

DXGET accepts data from the XTVP receiver via the 16-bit parallel I/O card (HP 98032A). One single HP 9845 ENTER statement is used with an integer array of 28800 words. We use DMA and NOFORMAT to ensure that no data are lost. The XTVP receiver outputs are two's complement 16-bit binary integers to match the HP 9845 integer word format. The keyboard is locked out during the ENTER to prevent loss of data.

After the HP 9845 data array is full, the array is written onto magnetic storage media for later processing by DXPRO. We elected not to collect and process simultaneously, for data integrity reasons and because the acquisition only takes 5 minutes. A more complicated program would be more prone to failure during data acquisition.

```
10     Progrev$="DXGETG"
20   ! DXGET  .. JAN 16 80. GET DIGITAL RCVR XTVP DATA.
30   ! DXGETG .. SEPT 16 80. OPERATOR INPUTS THE NUMBER OF SCANS TO READ.
40   !
50     OPTION BASE 1
60     SERIAL
80   !
90     PRINT ""
100    PRINT Progrev$;" TAKES XTVP DATA FROM THE DIGITAL RECEIVER FOR THE SPECIF
IED"
110    PRINT "NUMBER OF DATA CYCLES.  A DATA CYCLE IS ONE REPETION OF EACH OF "
120    PRINT "THE TEN VARIABLES."
130  !
140    PRINT "THE USER CAN ENTER THE NUMBER OF DATA CYCLES WISHED OR CAN LEAVE"
150    PRINT "THAT PARAMETER (Ncyc) AT IT'S DEFAULT"
160  !
170    PRINT "THERE IS ONE DATA CYCLE PER XTVP REVOLUTION. "
180  !
190    PRINT "FOR REAL TIME DATA USE NCYC=2880 TO ALLOW FOR PRE-DROP TIME"
200    PRINT "FOR PLAYBACK USE NCYC=1800 IF COMPUTER IS STARTED A FEW SECONDS PR
IOR TO DROP"
210    PRINT LIN(1)
220  !
230    Ncyc=2880
240    DISP "ENTER THE NO. DATA CYCLES TO TAKE FROM THE DIG RCVR.  THE DEFAULT I
S";Ncyc;
250    INPUT "",Ncyc
260    Nword=Ncyc*10
270    PRINT "THE NUMBER OF DATA CYCLES WILL BE ";Ncyc;" FOR THIS RUN"
271    PRINT "THIS WILL TAKE ";Ncyc/8;" SECONDS AT 8 HZ ROTATION FREQ."
290  !
300    INTEGER Din(32000)
310    Nword=Ncyc*10
320    REDIM Din(Nword)
330    DIM Comment$[160]
340  !
350    DISP "PUSH CONT TO START RECORDING FROM DIGITAL RECEIVER"
360    BEEP
370    PAUSE
```

```
380   !
390     OUTPUT 9;"R"                        ! GET REAL TIME
400     ENTER 9;Comment$
410   !
420     DISP Comment$;" GETTING DATA FROM DIGITAL RECEIVER NOW. "
430     SYSTEM TIMEOUT OFF
440     SUSPEND INTERACTIVE
450     ENTER 11 WDMA Nword NOFORMAT;Din(*)
460     RESUME INTERACTIVE
470     SYSTEM TIMEOUT ON
480     BEEP
490 !                                       STORE JUST-READ-IN DATA
500     EDIT "OUTPUT FILE NAME ?",File$
501     ASSIGN #2 TO File$,Ret
502     IF Ret<>0 THEN 510
503       DISP "FILE NAME ";File$;" EXISTS.  USE ANOTHER FILE NAME.  ";
504       GOTO 500
510   !
520     IF LEN(File$)=0 THEN 480
530   !
540     EDIT "COMMENTS ?",Comment$
550   !
560     ASSIGN #2 TO File$,Ret
570     IF Ret<>1 THEN 500
580     GOTO 640
590   !
600     DISP ERRM$;" WHILE CREATING ";File$;".   PUSH CONT USING ANOTHER DISC"
610     PAUSE
620     GOTO 500
630   !
640     ON ERROR GOTO 600
650     CREATE File$,Nword*4/256+5
660     OFF ERROR
670   !
680     ASSIGN #2 TO File$
690     READ #2,1
700     PRINT #2;Comment$
710     PRINT #2;Din(*)
720     ASSIGN #2 TO *
730   !
731     DISP Progrev$;" FINISHED"
740     BEEP
750     END
```

Program PADOC, Sample Run

PADOC is a program that computes the magnetic field components needed for data processing by DXPRO. The operator enters the date and position, and the program evaluates a spherical polynomial model. The program was modified by Jagit Hayre to run on the HP 9845 in BASIC. The original FORTRAN program was purchased from NOAA EDIS/NGSDC (D62), 325 Broadway, Boulder, Colorado 80303, (303) 497-6478. The model currently used is USWC75, but more refined models will soon be available.

The following page shows operator input and program output for 40°30'N and 150°55'W on 30 March 1981. The results for horizontal and vertical intensity in Gauss (10^{-4} tesla) are 0.2408963 and -0.3883425. Note that the vertical intensity is taken to be <0 in the northern hemisphere. This is the opposite of some conventions.

```
PADDOCK 02...........CALCULATION OF THE EARTH'S MAGNETIC HORIZONTAL
 (JUL '80)           AND VERTICAL INTENSITY FOR A GIVEN DATE AND
                     POSITION......


ARE THE GEODETIC OR GEOCENTRIC VALUES DESIRED FOR A GIVEN POSITION?
  (GEODETIC/GEOCENTRIC)
GEODETIC
GEODETIC VALUES WILL BE CALCULATED FOR A GIVEN DATE AND POSITION
IS A LIST OF THE AVAILABLE MODELS DESIRED? (YES/NO)
YES

THERE ARE PRESENT 1 MODELS WHOSE NAMES ARE:
  1  USWC75

MODEL 1 (USWC75) IS THE ONLY AVAILABLE MODEL--- USED BY DEFAULT
INPUT DATE: DAY, MONTH, YEAR
30,3,81

GIVEN DATE: 30/  3/ 1981
WILL THE GIVEN POSITION'S LATITUDE BE NORTH OR SOUTH? (N/S)
N
WILL THE GIVEN POSITION'S LONGITUDE BE EAST OR WEST? (E/W)
W


      POSITION               HORIZONTAL   VERTICAL
  LATITUDE     LONGITUDE     INTENSITY    INTENSITY
DEG   MIN N   DEG   MIN W     (GAUSS)      (GAUSS)

INPUT POSITION:   LATITUDE (DEG,MIN),      LONGITUDE (DEG,MIN)
40,30,150,55
 40  30.00   150  55.00      .2408963    -.3883425
INPUT POSITION:   LATITUDE (DEG,MIN),      LONGITUDE (DEG,MIN)
```

Listing of Program PADOC

```
10    ! **********************************************************************
20    !   PROGRAM PADDOCK-- CALCULATION OF THE EARTH'S MAGNETIC HORIZONTAL
30    !                     AND VERTICAL INTENSITY FOR A GIVEN DATE AND POSITION
35    !                     USING VARIOUS MODELS STORED IN DATA STATEMENTS
36     !
41     ! This program is a modification of a FORTRAN program of spherical
42     ! harmonic models for the earth's magnetic field, model AWC75,
43     ! from U.S. Dept. of Commerce, NOAA, NGSDC (D62), Environmental Data
44     ! Service, Boulder, Colorado, 80302.
50    !
60    !
70    !   INPUT REQUIRED FOR THIS PROGRAM IS:
80    !      1)  ARE THE GEODETIC OR GEOCENTRIC VALUES TO BE CALCULATED FOR THE
                  GIVEN DATE AND POSITION?
90    !      2)  IS A LIST OF THE AVAILABLE MODELS DESIRED?
100   !      3)  IF THE # OF AVAILABLE MODELS<>0 THEN  ENTER THE MODEL # OF THE
                  DESIRED MODEL TO BE USED FOR THE CALCULATION
110   !      4)  ENTER THE DATE: DAY, MONTH, YEAR.
120   !      5)  WILL THE GIVEN POSITION'S LATITUDE BE NORTH OR SOUTH?
130   !      6)  WILL THE GIVEN POSITION'S LONGITUDE BE EAST OR WEST?
140   !      7)  ENTER POSITION: DEG MIN (LAT) DEG MIN (LONG)
                   **** PROGRAM OUTPUTS MAGNETIC INTENSITIES IN GAUSS ****
150   !      8)  REPEAT STEP (7) AS DESIRED...
160   !
170   !
180   !
190   !    PADDOCK 01...... ORIGINAL FORTRAN PROGRAM
200   !    PADDOCK 02...... FORTRAN PROGRAM CONVERTED TO RUN ON THE HP 9845B
210   !                                BY J. HAYRE , JULY 1980
220   !
230        PRINT "PADDOCK 02...........CALCULATION OF THE EARTH'S MAGNETIC HORIZO
NTAL "
240        PRINT " (JUL '80)           AND VERTICAL INTENSITY FOR A GIVEN DATE AN
D"
250        PRINT "                     POSITION......"
260        PRINT LIN(1)
270   ! **********************************************************************
```

```
*
280   !
290   !
300   !
310   !
320   ! C      THIS PROGRAM DEMONSTRATES THE USE OF FUNCTIONS NGDXYZ AND NGCXYZ
330   ! C      TO COMPUTE VALUES OF THE GEOMAGNETIC ELEMENTS, AS DEFINED BY A
340   ! C      SPECIFIED  MODEL OF SPHERICAL HARMONIC COEFFICIENTS, FOR A GIVEN
350   ! C      TIME AND FOR A GIVEN GEODETIC OR GEOCENTRIC POSITION.
360   ! C      THE SHC'S OF THE AVAILABLE MODELS ARE CONTAINED IN DATA
             STATEMENTS IN FUNCTION NGDXYZ.
370   ! C
380   ! C      SAMPLE CALLS
390   ! C
400   ! C          N = NGDXYZ( YEAR, GDLAT, ELONG, GDALT, MODEL, ENTRY )
410   ! C
420   ! C              YEAR.......THE DATE IN YEARS
430   ! C              GDLAT......GEODETIC NORTH LATITUDE, IN DEGREES
440   ! C              ELONG......EAST LONGITUDE, IN DEGREES
450   ! C              GDALT......ALTITUDE ABOVE THE GEOID, IN KILOMETERS
460   ! C              MODEL......ORDINAL OF MODEL THAT IS TO BE USED
470   !                ENTRY......=0 FOR SIMPLE CALL TO NGDXYZ ( NO ENTRY PT )
480   ! C      WHEN THE ABOVE ENTRY IS USED, ALL VALUES ARE REFERENCED TO THE
490   ! C      INTERNATIONAL ELLIPSOID OF 1961.  THIS IS THE ENTRY THAT WOULD
500   ! C      NORMALLY BE USED.
510   ! C
520   ! C          N = NGDXYZ( YEAR, GCLAT, ELONG, GCALT, MODEL, ENTRY )
530   ! C
540   ! C              GCLAT......GEOCENTRIC NORTH LATITUDE, IN DEGREES
550   ! C              GCALT......ALTITUDE ABOVE THE SPHERE OF RADIUS 6371.2KM, IN
 KM
560   !                ENTRY......=1 FOR CALL TO ENTRY POINT NGCXYZ IN FUNCTION
 NGDXYZ
570   ! C
580   ! C      WHEN THE ABOVE ENTRY IS USED, ALL VALUES ARE REFERENCED TO THE
590   ! C      SPHERICAL EARTH WHOSE RADIUS IS 6371.2KM.
600   ! C
610          RAD
620          OPTION BASE 1
630          COM X,Y,Z,Xdot,Ydot,Zdot,Models,Name$(20),Xmn(900),Ymn(900),Zmn(900
)
640   ! C
650   ! C      FUNCTION NGDXYZ RETURNS THE MAGNETIC ELEMENTS X(NORTHWARD
660   ! C      INTENSITY), Y(EASTWARD INTENSITY), AND Z(DOWNWARD INTENSITY),
670   ! C      AND THEIR ANNUAL RATES, VIA COMMON . THE UNITS ARE
680   ! C      GAMMAS (NANOTESLAS) AND GAMMAS/YEAR (NANOTESLAS/YEAR). THESE
690   ! C      VALUES APPLY TO THE DATE AND POSITION USED IN THE CALL
700   ! C      STATEMENT.
710   !
720   !
730   !          DETERMINE IF GEODETIC OR GEOCENTRIC VALUES ARE DESIRED
740   !
750          INPUT "ARE THE GEODETIC OR GEOCENTRIC VALUES DESIRED FOR A GIVEN PO
SITION?          (GEODETIC/GEOCENTRIC)",Geotype$
760          IF (Geotype$="GEOCENTRIC") OR (Geotype$="GEODETIC") THEN 880
770          BEEP
780          DISP "MISSPELLED DESIRED TYPE--- ",Geotype$
790          GOTO 750
```

AD-A115 659 WASHINGTON UNIV SEATTLE APPLIED PHYSICS LAB F/G 8/3
DESIGN, OPERATION AND PERFORMANCE OF AN EXPENDABLE TEMPERATURE --ETC(U)
MAY 82 T B SANFORD, R G DREVER, J H DUNLAP N00014-80-C-0347
UNCLASSIFIED APL-UW-8110 NL

2 of 2
AD A
115659

END
DATE
FILMED
7-82
DTIC

```
800   ! C
810   ! C     FIRST WE MAKE A DUMMY CALL TO NGDXYZ. THIS FIRST CALL WILL SIMPLY
820   ! C     READ THE SHC MODEL HEADER CARDS, PLACE IN MODELS THE NUMBER OF SHC
830   ! C     MODELS, AND PLACE IN NAMES THE INDIVIDUAL MODEL NAMES. THIS DUMMY
840   ! C     CALL IS NORMALLY UNNECESSARY, IT IS NEEDED HERE ONLY BECAUSE WE WIS
H
850   ! C     TO PRINT THE NUMBER OF MODELS AND THEIR NAMES BEFORE MAKING AN ACTU
AL
860   ! C     CALL TO NGDXYZ.
870   ! C
880           PRINT USING "K";Geotype$," VALUES WILL BE CALCULATED FOR A GIVEN DA
TE AND POSITION"
890           N=FNNgdxyz(1999,0,0,0,0,0)
900           INPUT "IS A LIST OF THE AVAILABLE MODELS DESIRED? (YES/NO)",Respons
e$
910           IF Response$="NO" THEN 990
920   !
930   !       OUTPUT THE LIST OF AVAILABLE MODELS
940   !
950           PRINT USING "/3(K)";"THERE ARE PRESENT ",Models," MODELS WHOSE NAME
S ARE: "
960           FOR I=1 TO Models
970           PRINT USING "1X,DD,2X,K/";I,Name$(I)  !  OUTPUT AVAILABLE MODEL NAM
ES
980           NEXT I
990           Model=1
1000          IF Models<>1 THEN 1060
1010          PRINT USING "K";"MODEL 1 (",Name$(1),") IS THE ONLY AVAILABLE MODEL
--- USED BY DEFAULT"
1020          GOTO 1110
1030  !
1040  !       INPUT THE DESIRED MODEL NUMBER
1050  !
1060          INPUT "ENTER THE NUMBER OF THE DESIRED MODEL",Model
1070          IF (Model>=1) OR (Model<=Models) THEN 1110
1080          BEEP
1090          DISP "MODEL NUMBER ",Model,"OUT OF RANGE ---- MAX MODEL NUMBER IS "
,Models
1100          GOTO 1060
1110          IF Models>1 THEN PRINT USING "/3(K)";"MODEL ",Model," (",Name$(Mode
l),") IS BEING USED FOR THIS RUN"
1120          Rod=.017453293    ! RAD/DEGREE CONVERSION FACTOR
1130          Rod=Rod+SIN(180.0*Rod)/180.0
1140          Rod=Rod+SIN(180.0*Rod)/180.0
1150          Rom2=2*Rod/60.0
1160 !
1170 ! C
1180 ! C
1190 ! C     READ IN THE DATE AND POSITION DIRECTION
1200 !
1210          INPUT "INPUT DATE: DAY, MONTH, YEAR",Day,Month,Year
1211          IF Year<1900 THEN Year=Year+1900
1220          Date=Year+Month/12+Day/365
1230          PRINT USING "/K,2(DD,K),DDDD";"GIVEN DATE: ",Day,"/ ",Month,"/ ",Ye
ar
```

```
1240         INPUT "WILL THE GIVEN POSITION'S LATITUDE BE NORTH OR SOUTH? (N/S)"
,Dirns$
1250         IF (Dirns$="N") OR (Dirns$="S") THEN 1290
1260         BEEP
1270         DISP "DIRECTION MUST BE N OR S ---- ",Dirns$," IS ILLEGAL "
1280         GOTO 1240
1290         INPUT "WILL THE GIVEN POSITION'S LONGITUDE BE EAST OR WEST? (E/W)",
Direw$
1300         IF (Direw$="E") OR (Direw$="W") THEN 1370
1310         BEEP
1320         DISP "DIRECTION MUST BE E OR W ---- ",Direw$," IS ILLEGAL "
1330         GOTO 1290
1340 !
1350 !       PRINT TABLE HEADINGS
1360 !
1370         PRINT LIN(2)
1380         PRINT "       POSITION                 HORIZONTAL   VERTICAL"
1390         PRINT "  LATITUDE    LONGITUDE       INTENSITY    INTENSITY"
1400         PRINT USING "2(K,1A),K/";"DEG  MIN ",Dirns$,"   DEG  MIN ",Direw$,"
      (GAUSS)       (GAUSS)"
1410 !
1420 !       READ IN THE POSITION (ACTUAL LOOPING OCCURS HERE)
1430 !
1440 Input:   INPUT "INPUT POSITION:   LATITUDE (DEG,MIN),     LONGITUDE (DEG,MI
N)",Alatdeg,Alatmin,Elondeg,Elonmin
1450         Alat=Alatdeg+Alatmin/60.0
1460         Elon=Elondeg+Elonmin/60.0
1470         IF Dirns$="S" THEN Alat=-Alat
1480         IF Direw$="W" THEN Elon=-Elon
1490         Alt=0
1500         IF Geotype$="GEOCENTRIC" THEN 1640
1510 !
1520 ! C     OBTAIN VALUES FOR THE GIVEN DATE AT THE GIVEN GEODETIC POSITION.
1530 ! C
1540 !
1550         N=FNNgdxyz(Date,Alat,Elon,Alt,Model,0)
1560 !
1570 ! C     WE NOW HAVE VALUES AND RATES FOR MAGNETIC ELEMENTS X, Y, AND Z.
1580 ! C     VALUES FOR THE OTHER GEOMAGNETIC ELEMENTS, IF NEEDED, MUST BE
1590 ! C     COMPUTED.
1600 ! C
1610 ! C
1620 ! C     HORIZONTAL INTENSITY
1630 ! C
1640         H=SQR(X^2+Y^2)
1650         Hdot=(SQR((X+Xdot)^2+(Y+Ydot)^2)-SQR((X-Xdot)^2+(Y-Ydot)^2))/2
1660 ! C     HDOT = (X*XDOT + Y*YDOT)/H    H GT 1000GAMMAS
1670 ! C
1680 ! C     TOTAL INTENSITY
1690 ! C
1700         F=SQR(X^2+Y^2+Z^2)
1710 ! C     F = SQR( H**2 + Z**2 )
1720         Fdot=(SQR((X+Xdot)^2+(Y+Ydot)^2+(Z+Zdot)^2)-SQR((X-Xdot)^2+(Y-Ydot)
^2+(Z-Zdot)^2))/2
1730 ! C     FDOT = (X*XDOT + Y*YDOT + Z*ZDOT)/F OR
1740 ! C     FDOT = (H*HDOT + Z*ZDOT)/F              F GT 1000GAMMAS
```

```
1750 ! C
1760 ! C      DECLINATION
1770 ! C
1780          D=FNAtan2(Y,X)/Rod
1790          Ddot=(FNAtan2(Y+Ydot,X+Ydot)-FNAtan2(Y-Ydot,X-Xdot))/Rom2
1800 ! C
1810 ! C      INCLINATION
1820 ! C
1830          Dip=FNAtan2(Z,H)/Rod
1840          Dipdot=(FNAtan2(Z+Zdot,H+Hdot)-FNAtan2(Z-Zdot,H-Hdot))/Rom2
1850 ! C
1860 ! C
1870 ! C
1880          IF Geotype$="GEODETIC" THEN M9
1890 ! C
1900 ! C
1910 ! C      OBTAIN GEOCENTRIC VALUES FOR THE GIVEN GEOCENTRIC POSITION
1920 ! C
1930          N=FNNgdxyz(Date,Alat,Elon,Alt,Model,1)
1940 M9:      ! CONVERT Y,Z TO GAUSS FOR PRINTING (1 GAUSS= 1E5 NANOTESLAS)
1950          Z=-Z/1E5
1960          H=H/1E5
1970          PRINT USING "2(3D,1X,3D.DD,2X,1X),2(3D.DDDDDD,2X)";Alatdeg,Alatmin
,Elondeg,Elonmin,H,Z
1980          GOTO Input
1990          END
2000 !
2010 !
2020    DEF FNNgdxyz(Yr,Alat,Elon,Alt,Kthmod,Entry)
2030          OPTION BASE 1
2040          COM X,Y,Z,Dx,Dy,Dz,Models,Model$(20),Xmn(900),Ymn(900),Zmn(900)
2050 ! C
2060 ! C FOR THE GIVEN YEAR, GEODETIC POSITION, ALTITUDE, AND MODEL, THIS
2070 ! C FUNCTION COMPUTES THE MAGNETIC ELEMENTS X, Y, Z, XDOT, YDOT, ZDOT,
2080 ! C AND RETURNS THEM IN COMMON.
2090 ! C
2100 ! C
2110 ! C      AT THE FIRST ENTRY, THIS FUNCTION READS A DECK OF 1 TO 20 MODELS.
2120 ! C      THIS DECK IS TERMINATED BY A CARD WITH 9999 IN CC 1-4.
2130 ! C
2140 ! C      P A R A M E T E R S
2150 ! C
2160 ! C          YR.............DATE IN YEARS / 1975.0
2170 ! C          ALAT...........NORTH LATITUDE IN DEGREES / 40.0
2180 ! C          ELON...........EAST LONGITUDE, IN DEGREES /  -103.0
2190 ! C          ALT............HEIGHT ABOVE THE GEOID IN KILOMETERS  /  100.0
2200 ! C          KTHMOD.........EITHER...THE ORDINAL OF THE MODEL, IE, 3 WILL
2210 ! C                                  CAUSE THE 3RD MODEL TO BE USED
2220 !            ENTRY..........=0 IMPLIES SIMPLE FUNCTION NGDXYZ CALL
2230 !                           =1 IMPLIES ENTRY NGCXYZ CALL.
2240 ! C
2250 ! C
2260 ! C      ON RETURN, THE VALUE OF NGDXYZ WILL INDICATE WHAT ERROR, IF ANY, OC
CURRED.
2270 ! C
2280 ! C      NGDXYZ = 0.....NO ERROR
2290 ! C             = -1....ERROR IN MODEL DATA RECORD. FATAL
2300 ! C             = -2....ARRAY G (WHEREIN THE SHC S OF THE MODELS ARE STORED)
```

```
 IS
2310 ! C                    NOT LARGE ENOUGH. (THE SIZE OF G IS GIVEN BY MAXGS).
 FATAL.
2320 ! C            = -3....MODEL SPECIFIED BY KTHMOD NOT FOUND. FATAL.
2330 !
2340 ! C            = 1.....YR OUTSIDE DATE LIMITS SET BY MODEL HEADER CARD
2350 ! C            = 2.....ALT OUTSIDE HEIGHT LIMITS SET BY HEADER CARD
2360 ! C            = 3.....BOTH YR AND ALT OUTSIDE LIMITS
2370 ! C
2380 ! C
2390 ! C
2400         DIM Ijs(20,3),Max(20,3),Epoch(20),Yrmin(20),Yrmax(20),Altmax(20),Al
tmin(20),G(600)
2410 ! C     THE SIZE OF ARRAY G IS PROBABLY UNREASONABLY LARGE FOR MOST USERS.
2420 ! C     IF ITS SIZE IS CHANGED, THEN THE VALUE OF MAXGS, AS SET IN THE
2430 ! C     FIRST DATA STATEMENT, MUST ALSO BE CHANGED.
2440 ! C
2450 ! C
2460         IF Entry=1 THEN Lngcxyz   ! ENTRY NGCXYZ SIMULATION
2470 ! C     ENTRY NGCXYZ SIMULATION
2480         Ngdgc=0
2490 A1:     READ Maxgs,Models
2500         DATA     600,      0
2510         READ Maxmod,Maxxyz
2520         DATA  20,     30
2530         IF Kthmod=0 THEN A2
2540         MAT Ijs=(0)
2550         MAT Yrmax=(2000)
2560         MAT Yrmin=(0)
2570         MAT Altmax=(1.00E11)
2580         MAT Altmin=(-1.00E11)
2590         READ Nthold,Killer
2600         DATA    -1,       1
2610 !
2620 ! ****************** MODEL "USWC75" ************************************
2630 !
2640 DATA 0,0,"USWC75", 1975.0, 12, 8, 0, 1967.0, 1980.0, -1.0, 100.0
2650 DATA 0,1,-30055.7,   0,      24.39,    0,      0,0
2660 DATA 1,1,-2017.0, 5670.5,   9.94, -10.29, 0,0
2670 DATA 0,2,-1932.0,   0   , -24.85,    0  ,   0,0
2680 DATA 1,2, 3001.3,-2044.4,   1.19,  -3.08,   0,0
2690 DATA 2,2, 1619.7,  -69.2,   3.10, -18.98,   0,0
2700 DATA 0,3, 1267.1,   0   ,  -3.74,    0  ,   0,0
2710 DATA 1,3,-2127.2, -343.5, -10.42,   6.68,   0,0
2720 DATA 2,3, 1259.4,  263.2,  -3.41,   2.13,   0,0
2730 DATA 3,3,  818.0, -208.5,  -3.70,  -3.53,   0,0
2740 DATA 0,4,  953.8,   0   ,    .46,    0  ,   0,0
2750 DATA 1,4,  786.1,  196.7,  -1.78,   4.65,   0,0
2760 DATA 2,4,  437.8, -257.0,  -3.69,    .96,   0,0
2770 DATA 3,4, -412.8,   20.1,  -2.06,    .87,   0,0
2780 DATA 4,4,  232.3, -287.5,  -1.60,  -1.37,   0,0
2790 DATA 0,5, -214.2,   0   ,    .31,    0  ,   0,0
2800 DATA 1,5,  357.4,   31.4,   -.34,   1.45,   0,0
2810 DATA 2,5,  256.1,  150.7,    .96,   2.04,   0,0
2820 DATA 3,5,  -42.8, -137.4,  -1.16,  -1.27,   0,0
2830 DATA 4,5, -166.7,  -81.9,   -.37,   1.34,   0,0
2840 DATA 5,5,  -58.9,   86.2,    .63,   1.04,   0,0
```

```
2850 DATA 0,6,   41.7,    0   ,    -.35,    0  ,    0,0
2860 DATA 1,6,   64.2,  -19.9,     .09,   -.65,    0,0
2870 DATA 2,6,   18.3,  105.6,    1.75,   -.03,    0,0
2880 DATA 3,6, -199.4,   60.8,    2.13,   -.61,    0,0
2890 DATA 4,6,    3.2,  -39.2,    -.06,  -1.01,    0,0
2900 DATA 5,6,   10.6,    1.8,     .92,   1.11,    0,0
2910 DATA 6,6, -108.5,   14.6,     .24,   1.48,    0,0
2920 DATA 0,7,   74.3,    0   ,     .45,    0  ,    0,0
2930 DATA 1,7,  -49.7,  -73.0,     .17,  -1.50,    0,0
2940 DATA 2,7,    5.4,  -27.9,     .57,   -.02,    0,0
2950 DATA 3,7,   24.8,   -5.2,     .87,    .49,    0,0
2960 DATA 4,7,  -11.8,    8.2,     .94,    .23,    0,0
2970 DATA 5,7,   -3.7,   13.9,     .02,   -.80,    0,0
2980 DATA 6,7,   15.0,  -21.0,     .13,    .17,    0,0
2990 DATA 7,7,     .3,   -9.3,    -.15,    .45,    0,0
3000 DATA 0,8,   12.4,    0   ,     .04,    0  ,    0,0
3010 DATA 1,8,    8.4,    6.9,     .37,   -.22,    0,0
3020 DATA 2,8,   -3.7,  -15.4,     .14,   -.36,    0,0
3030 DATA 3,8,  -11.7,    4.8,    -.11,   -.04,    0,0
3040 DATA 4,8,   -8.5,  -17.0,    -.48,   -.28,    0,0
3050 DATA 5,8,    5.9,   11.0,    -.27,    .40,    0,0
3060 DATA 6,8,    2.9,   15.5,     .55,   -.18,    0,0
3070 DATA 7,8,    7.1,   -9.6,    -.41,   -.70,    0,0
3080 DATA 8,8,    3.1,  -19.1,    -.17,    .04,    0,0
3090 DATA 0,9,   12.5,    0   ,   0   ,    0  ,    0,0
3100 DATA 1,9,    5.2,  -17.2,    0   ,    0  ,    0,0
3110 DATA 2,9,    1.5,   17.2,    0   ,    0  ,    0,0
3120 DATA 3,9,   -7.4,    4.2,    0   ,    0  ,    0,0
3130 DATA 4,9,   11.9,    -.1,    0   ,    0  ,    0,0
3140 DATA 5,9,    2.3,   -4.9,    0   ,    0  ,    0,0
3150 DATA 6,9,    -.4,    9.1,    0   ,    0  ,    0,0
3160 DATA 7,9,    2.9,   12.2,    0   ,    0  ,    0,0
3170 DATA 8,9,    1.6,   -2.9,    0   ,    0  ,    0,0
3180 DATA 9,9,    -.8,     .8,    0   ,    0  ,    0,0
3190 DATA 0,10,   -5.5,    0   ,   0   ,    0  ,    0,0
3200 DATA 1,10,   -2.0,      .2,   0   ,    0  ,    0,0
3210 DATA 2,10,    2.0,      .6,   0   ,    0  ,    0,0
3220 DATA 3,10,   -2.7,     -.5,   0   ,    0  ,    0,0
3230 DATA 4,10,   -4.0,     4.3,   0   ,    0  ,    0,0
3240 DATA 5,10,    9.1,    -4.0,   0   ,    0  ,    0,0
3250 DATA 6,10,    4.2,     2.7,   0   ,    0  ,    0,0
3260 DATA 7,10,   -2.2,    -2.0,   0   ,    0  ,    0,0
3270 DATA 8,10,    -.8,     4.3,   0   ,    0  ,    0,0
3280 DATA 9,10,    5.0,      .1,   0   ,    0  ,    0,0
3290 DATA 10,10,    2.1,    -4.5,   0   ,    0  ,    0,0
3300 DATA 0,11,    4.4,    0   ,   0   ,    0  ,    0,0
3310 DATA 1,11,   -3.1,     1.0,   0   ,    0  ,    0,0
3320 DATA 2,11,   -2.7,     2.4,   0   ,    0  ,    0,0
3330 DATA 3,11,    5.0,    -2.1,   0   ,    0  ,    0,0
3340 DATA 4,11,    -.3,     2.4,   0   ,    0  ,    0,0
3350 DATA 5,11,   -1.3,     3.2,   0   ,    0  ,    0,0
3360 DATA 6,11,   -1.0,     1.7,   0   ,    0  ,    0,0
3370 DATA 7,11,    1.0,     -.7,   0   ,    0  ,    0,0
3380 DATA 8,11,     .9,    -3.0,   0   ,    0  ,    0,0
3390 DATA 9,11,   -2.1,    -2.1,   0   ,    0  ,    0,0
3400 DATA 10,11,     .8,      .2,   0   ,    0  ,    0,0
3410 DATA 11,11,    -.5,     -.1,   0   ,    0  ,    0,0
```

```
3420 DATA 0,12,    -.7,    0   ,    0   ,    0  ,   0,0
3430 DATA 1,12,    0.0,    1.3,    0   ,    0  ,   0,0
3440 DATA 2,12,    1.6,   -1.8,    0   ,    0  ,   0,0
3450 DATA 3,12,     .4,     .9,    0   ,    0  ,   0,0
3460 DATA 4,12,   -1.5,     .1,    0   ,    0  ,   0,0
3470 DATA 5,12,   -1.2,   -1.8,    0   ,    0  ,   0,0
3480 DATA 6,12,    -.4,    1.4,    0   ,    0  ,   0,0
3490 DATA 7,12,   -3.6,   -1.1,    0   ,    0  ,   0,0
3500 DATA 8,12,     .6,     .1,    0   ,    0  ,   0,0
3510 DATA 9,12,     .8,    1.9,    0   ,    0  ,   0,0
3520 DATA 10,12,    -.3,   -3.3,    0   ,    0  ,   0,0
3530 DATA 11,12,    1.3,     .6,    0   ,    0  ,   0,0
3540 DATA 12,12,     .7,    1.5,    0   ,    0  ,   0,0
3550 !
3560 ! **********************************************************************
*
3570 !
3580 !
3590 ! **************** TERMINATION DATA HEADER CARD ***************************
*
3600 DATA 99,99,"END" ,  0    ,  0, 0, 0,      0,      0,    0,   0
3610 ! **********************************************************************
3620 !
3630 !
3640           Ngdxyz=0
3650           IF Models>0 THEN A10
3660           Ijnext=0
3670 A2:       I=Models+1
3680           IF I>Maxmod THEN A8
3690 ! C
3700 ! C        READ MODEL HEADER CARD
3710 ! C
3720           IF I=1 THEN RESTORE 2640      !   SELECT THE DATA FOR THE Ith MODEL
3730           IF I=2 THEN RESTORE 3600      !   TERMINATION DATA HEADER CARD IS
REQUIRED
3740 ! C       READ 102,  M, N, MODEL(I), EPOCH(I), (MAX(I,JJ), JJ = 1, 3),
3750           READ M,N,Model$(I),Epoch(I),Max(I,1),Max(I,2),Max(I,3),Yrmni,Yrmxi,
Altmni,Altmxi
3760           IF M=99 THEN A9     ! CHECK FOR TERMINATION MODEL HEADER CARD
3770           IF Kthmod<>0 THEN A3
3780 !         THIS LOOP SIMPLY COUNTS THE NUMBER OF MODELS AVAILABLE (BY THE DUMM
Y CALL TO NGDXYZ FROM THE MAIN PROGRAM)
3790           Models=Models+1
3800           GOTO A2
3810 A3:       IF (M<>0) OR (N<>0) THEN A81
3820           IF Altmni<>0 THEN Altmin(I)=Altmni
3830           IF Altmxi<>0 THEN Altmax(I)=Altmxi
3840           IF Yrmni<>0 THEN Yrmin(I)=Yrmni
3850           IF Yrmxi<>0 THEN Yrmax(I)=Yrmxi
3860           FOR J=1 TO 3
3870           IF Max(I,J)=0 THEN A4
3880           Max(I,J)=Max(I,J)+1
3890           Ijs(I,J)=Ijnext
3900           Ijnext=Ijnext+Max(I,J)^2
3910           NEXT J
3920 A4:       IF Ijnext>=Maxgs THEN A82
3930           Models=I
```

```
3940 !       CALCULATE THE NUMBER OF DATA STATEMENTS TO BE READ FOR THE DESIRED
  MODEL
3950         Ncards=Max(I,1)*(Max(I,1)+1)/2
3960         Maxg=Max(I,1)
3970         Maxdg=Max(I,2)
3980         Maxd2g=Max(I,3)
3990         Ij10=Ijs(I,1)
4000         Ij20=Ijs(I,2)
4010         Ij30=Ijs(I,3)
4020         Ij1=Ij10+1
4030         FOR Ij=Ij1 TO Ijnext
4040         G(Ij)=0
4050         NEXT Ij
4060         FOR Nc=2 TO Ncards
4070 ! C
4080 ! C    READ MODEL DATA CARD
4090 ! C
4100 ! C    READ 104,  M, N, GMN, HMN, DGMN, DHMN, D2GMN, D2HMN, MODELC
4110         READ M,N,Gmn,Hmn,Dgmn,Dhmn,D2gmn,D2hmn
4120         Ij1=Ij10+N*Maxg+M+1
4130         Ij2=Ij20+N*Maxdg+M+1
4140         Ij3=Ij30+N*Maxd2g+M+1
4150         G(Ij1)=Gmn
4160         IF Dgmn<>0 THEN G(Ij2)=Dgmn
4170         IF D2gmn<>0 THEN G(Ij3)=D2gmn
4180         IF M=0 THEN A6
4190         Ji1=Ij10+(M-1)*Maxg+N+1
4200         Ji2=Ij20+(M-1)*Maxdg+N+1
4210         Ji3=Ij30+(M-1)*Maxd2g+N+1
4220         G(Ji1)=Hmn
4230         IF Dhmn<>0 THEN G(Ji2)=Dhmn
4240         IF D2hmn<>0 THEN G(Ji3)=D2hmn
4250 A6:     NEXT Nc
4260         CALL Smigau(G(*),Ij10+1,Maxg,Maxg)
4270         IF Maxdg<>0 THEN CALL Smigau(G(*),Ij20+1,Maxdg,Maxdg)
4280         IF Maxd2g<>0 THEN CALL Smigau(G(*),Ij30+1,Maxd2g,Maxd2g)
4290         GOTO A2
4300 A8:     IF M<>99 THEN A81
4310 A9:     IF Models=0 THEN A81
4320         IF Kthmod=0 THEN RETURN Ngdxyz
4330 A10:    IF Kthmod=Nthold THEN A20
4340         IF ABS(Kthmod)<=Maxmod THEN A12
4350         FOR I=1 TO Models
4360         IF Kthmod<>Model(I) THEN A11
4370         Nthmod=I
4380         GOTO A13
4390 A11:    NEXT I
4400         GOTO A83
4410 A12:    IF (Kthmod<1) OR (Kthmod>Models) THEN A83
4420         Nthmod=Kthmod
4430 A13:    Nthold=Kthmod
4440         Maxg=Max(Nthmod,1)
4450         Maxdg=Max(Nthmod,2)
4460         Maxd2g=Max(Nthmod,3)
4470         Ij10=Ijs(Nthmod,1)
4480         Ij20=Ijs(Nthmod,2)
4490         Ij30=Ijs(Nthmod,3)
```

```
4500 A20:     CALL Vecxyz(Alat,Elon,Alt,Maxg,Ngdgc)
4510 ! C
4520 ! C      TEST FOR NON-FATAL ERRORS
4530 ! C
4540          IF (Yr<Yrmin(Nthmod)) OR (Yr>Yrmax(Nthmod)) THEN Ngdxyz=1
4550          IF (Alt<Altmin(Nthmod)) OR (Alt>Altmax(Nthmod)) THEN Ngdxyz=Ngdxyz+
2
4560          X=0
4570          Y=0
4580          Z=0
4590          Ij=Ij10
4600          Ji0=0
4610          FOR I=1 TO Maxg
4620          Ji=Ji0
4630          Ji0=Ji0+Maxxyz
4640          FOR J=1 TO Maxg
4650          Ij=Ij+1
4660          Ji=Ji+1
4670          Gmnij=G(Ij)
4680          X=X+Xmn(Ji)*Gmnij
4690          Y=Y+Ymn(Ji)*Gmnij
4700 A21:     Z=Z+Zmn(Ji)*Gmnij
4710          NEXT J
4720 A22:     NEXT I
4730          Dx=0
4740          Dy=0
4750          Dz=0
4760          IF Maxdg<=0 THEN RETURN Ngdxyz
4770          Ij=Ij20
4780          Ji0=0
4790          FOR I=1 TO Maxdg
4800          Ji=Ji0
4810          Ji0=Ji0+Maxxyz
4820          FOR J=1 TO Maxdg
4830          Ij=Ij+1
4840          Ji=Ji+1
4850          Dgmnij=G(Ij)
4860          Dx=Dx+Xmn(Ji)*Dgmnij
4870          Dy=Dy+Ymn(Ji)*Dgmnij
4880 A23:     Dz=Dz+Zmn(Ji)*Dgmnij
4890          NEXT J
4900 A24:     NEXT I
4910          Del=Yr-Epoch(Nthmod)
4920          IF Maxd2g>0 THEN A30
4930          X=X+Del*Dx
4940          Y=Y+Del*Dy
4950          Z=Z+Del*Dz
4960          RETURN Ngdxyz
4970 A30:     D2x=0
4980          D2y=0
4990          D2z=0
5000          Ij=Ij30
5010          Ji0=0
5020          FOR I=1 TO Maxd2g
5030          Ji=Ji0
5040          Ji0=Ji0+Maxxyz
5050          FOR J=1 TO Maxd2g
```

```
5060          Ij=Ij+1
5070          Ji=Ji+1
5080          Dgmnij=G(Ij)
5090          D2x=D2x+Xmn(Ji)*Dgmnij
5100          D2y=D2y+Ymn(Ji)*Dgmnij
5110 A31:     D2z=D2z+Zmn(Ji)*Dgmnij
5120          NEXT J
5130 A32:     NEXT I
5140          Del2=Del*Del
5150          X=X+Del*Dx+Del2*D2x
5160          Y=Y+Del*Dy+Del2*D2y
5170          Z=Z+Del*Dz+Del2*D2z
5180          Del2=2*Del
5190          Dx=Dx+Del2*D2x
5200          Dy=Dy+Del2*D2y
5210          Dz=Dz+Del2*D2z
5220          RETURN Ngdxyz
5230 !            ENTRY  NGCXYZ
5240 ! C    *                ( YR, ALAT, ELON, ALT, NTHMOD )                  C
 OUT
5250 ! C
5260 ! C       THIS ENTRY IS USED WHEN POSITION AND ALTITUDE ARE GEOCENTRIC. THE
5270 ! C       RETURNED MAGNETIC ELEMENTS ARE GEOCENTRIC.
5280 ! C
5290 Lngcxyz:Ngdgc=1
5300          GOTO A1
5310 ! C
5320 ! C       ERROR RETURNS
5330 ! C
5340 ! C       NOTE THAT A SECOND ERROR USES A DIVISION BY ZERO TO ABORT THE
 PROGRAM
5350 ! C
5360 ! C
5370 ! C       ERROR IN DATA CARDS OF MODEL
5380 A81:     Mistek=1
5390          PRINT "MISTEK=1 AT A81 --- PROBABLE ERROR IN DATA STATEMENTS OF THE
 MODEL"
5400          GOTO A89
5410 ! C
5420 ! C       ARRAY G INADEQUATELY DIMENSIONED
5430 ! C
5440 A82:     Mistek=2
5450          PRINT "MISTEK=2 AT A82 --- ARRAY G INADEQUATELY DIMENSIONED"
5460          GOTO A89
5470 ! C
5480 ! C       MODEL SPECIFIED BY KTHMOD NOT FOUND
5490 ! C
5500 A83:     Mistek=3
5510          PRINT "MISTEK=3 AT A83 --- MODEL SPECIFIED BY KTHMOD NOT FOUND"
5520          GOTO A89
5530 A89:     Ngdxyz=-Mistek/Killer
5540          Killer=0
5550          RETURN Ngdxyz
5560          FNEND
5570 !
5580 !
5590 !
```

```
5600          SUB Vecxyz(Alat,Elon,Alt,Maxnew,Nycen)
5610          OPTION BASE 1
5620          RAD
5630          COM X,Y,Z,Dx,Dy,Dz,Models,Model$(20),Xmn(900),Ymn(900),Zmn(900)
5640          DIM P(900),D(900),Rxy(30),Rz(30),Sm(30),Cm(30)
5650          READ Rod,Oldth,Oldam,Oldlat,Oldalt,Oldr
5660          DATA  0.017453293, 9999., 9999.,   9999.,   9999., -99.
5670          READ Maxi,New,Radius,Max,Ntceno
5680          DATA  30,   1, 6371.2,  -1,      -1
5690          IF Max=Maxnew THEN GOTO B2
5700          Nyceno=-1
5710          Max=Maxnew
5720          IF New=0 THEN GOTO B2
5730          New=0
5740          Maxi1=Maxi+1
5750          Maxi2=Maxi+2
5760 ! C              SET UP CONSTANTS IN LOWER TRIANGULAR OF P
5770          FOR J=1 TO Maxi
5780          Ji=J-Maxi
5790          A=(J-2)*(J-2)
5800          B=(2*J-3)*(2*J-5)
5810          FOR I=1 TO J
5820          Ji=Ji+Maxi
5830 B1:      P(Ji)=(A-(I-1)^2)/B
5840          NEXT I
5850          NEXT J
5860 B2:      Am=Elon*Rod
5870 !
5880          IF Nycen=Nyceno THEN GOTO B3
5890          Nyceno=Nycen
5900          Oldlat=9999
5910          Oldth=999
5920          Oldr=-1
5930 B3:      IF Nycen<>0 THEN B9
5940 ! C
5950 ! C          POSITIONS ARE GEODETIC
5960 ! C          XMN, YMN, ZMN WILL BE GEODETIC
5970 ! C
5980          Vlat=Alat
5990          Valt=Alt
6000          IF (Vlat=Oldlat) AND (Valt=Oldalt) THEN B10
6010          Oldlat=Vlat
6020          Oldalt=Valt
6030          Gg=Vlat^2
6040          Rs=6378.160+Gg*(-.0064601509+Gg*(6.39897239E-7+Gg*(-2.3568098E-11+G
g*3.44645500E-16)))
6050          Del=Vlat*(1.16781720E-4+Gg*(-2.34129534E-8+Gg*(1.34088770E-12-Gg*2.
84450572E-17)))
6060          Hrs=Valt+Rs
6070          Beta=Rs*Del/Hrs
6080          Th=(90.0-Vlat)*Rod+Beta
6090          R=(Hrs-Beta*Valt*Del*.5)/Radius
6100          Bbeta=Beta^2
6110          Beta=Beta*(1+Bbeta*(-1/6.0+Bbeta/120.0))
6120          IF ABS(Beta)<1 THEN B8
6130 !
```

```
6140 !          SIMULATION OF FORTRAN "SIGN(A,B)" FUNCTION
6150            IF Beta>=0 THEN Beta=1
6160            IF Beta<0 THEN Beta=-1
6170 !
6180            Cbeta=0
6190            GOTO B10
6200 B8:        Cbeta=SQR(1-Beta^2)
6210            GOTO B10
6220 !
6230 ! C             POSITIONS ARE GEOCENTRIC
6240 ! C             XMN, YMN, ZMN WILL BE GEOCENTRIC
6250 ! C
6260 B9:        R=1+Alt/Radius
6270            Th=(90.0-Alat)*Rod
6280            Beta=0
6290 B10:       IF Th=Oldth THEN B20
6300 ! C                       COMPUTE GAUSS PMN, DPMN
6310            Oldth=Th
6320            U=COS(Th)
6330            V=SIN(Th)
6340            IF V=0 THEN V=1.0E-20
6350            P(1)=1
6360            D(1)=0
6370            Ii=1
6380            FOR I=2 TO Max
6390            I1i1=Ii
6400            Ii=Ii+Maxi1
6410            I1i=Ii-1
6420            P(Ii)=V*P(I1i1)
6430            D(Ii)=U*P(I1i1)+V*D(I1i1)
6440            P(I1i)=U*P(I1i1)
6450            D(I1i)=U*D(I1i1)-V*P(I1i1)
6460 B12:       NEXT I
6470            Ii=1
6480            FOR I=3 TO Max
6490            I2j1=Ii
6500            Ji2=Ii+1
6510            Ii=Ii+Maxi1
6520            I2j=Ii-1
6530            FOR J=I TO Max
6540            I2j2=I2j1
6550            I2j1=I2j
6560            I2j=I2j+Maxi
6570            Ji2=Ji2+1
6580            P(I2j)=U*P(I2j1)-P(Ji2)*P(I2j2)
6590            D(I2j)=U*D(I2j1)-P(Ji2)*D(I2j2)-V*P(I2j1)
6600 B13:       NEXT J
6610            NEXT I
6620 ! C
6630 ! C        STORE SINES AND COSINES OF LONGITUDE
6640 ! C
6650 B20:       IF Am=Oldam THEN B30
6660            Oldam=Am
6670            Cm(2)=COS(Am)
6680            Sm(2)=SIN(Am)
6690            Cm(1)=1
```

```
6700           Sm(1)=0
6710           FOR I=3 TO Max
6720           Sm(I)=Sm(I-1)*Cm(2)+Cm(I-1)*Sm(2)
6730           Cm(I)=Cm(I-1)*Cm(2)-Sm(I-1)*Sm(2)
6740 B22:      NEXT I
6750 ! C
6760 ! C       STORE POWERS OF R
6770 ! C
6780 B30:      IF R=Oldr THEN B40
6790           Oldr=R
6800           Rxy(1)=1/R/R
6810           Rz(1)=-Rxy(1)
6820           FOR I=2 TO Max
6830           Rxy(I)=Rxy(I-1)/R
6840           Rz(I)=-I*Rxy(I)
6850           NEXT I
6860 ! C
6870 ! C                   COMPUTE XMN, YMN, ZMN ARRAYS
6880 ! C
6890 B40:      J1=1
6900           FOR J=2 TO Max
6910           J1=J1+Maxi
6920           Xmn(J1)=Rxy(J)*D(J1)
6930 B44:      Zmn(J1)=Rz(J)*P(J1)
6940           NEXT J
6950           V1=1/V
6960           Em=V1
6970           Ii=1
6980           FOR I=2 TO Max
6990           Cmi=Cm(I)
7000           Smi=Sm(I)
7010           Ij=Ii+1
7020           Ji=Ii
7030           Ii=Ii+Maxi1
7040           FOR J=I TO Max
7050           Ij=Ij+Maxi
7060           Ji=Ji+1
7070           Rxyj=Rxy(J)
7080           Rdij=Rxyj*D(Ij)
7090           Xmn(Ij)=Cmi*Rdij
7100           Xmn(Ji)=Smi*Rdij
7110           Pij=P(Ij)
7120           Epr=Em*Pij*Rxyj
7130           Ymn(Ij)=Epr*Smi
7140           Ymn(Ji)=-Epr*Cmi
7150           Rp=Rz(J)*Pij
7160           Zmn(Ij)=Cmi*Rp
7170           Zmn(Ji)=Smi*Rp
7180 B45:      NEXT J
7190 B46:      Em=Em+V1
7200           NEXT I
7210 ! C
7220           IF Beta=0 THEN B50
7230           J1=0
7240           FOR I=1 TO Max
7250           Ij=J1
7260           J1=J1+Maxi
```

```
7270          FOR J=1 TO Max
7280          Ij=Ij+1
7290          IF Ij=1 THEN B48
7300          Xij=Xmn(Ij)
7310          Zij=Zmn(Ij)
7320          Xmn(Ij)=Cbeta*Xij+Beta*Zij
7330          Zmn(Ij)=Cbeta*Zij-Beta*Xij
7340 B48:     NEXT J
7350 B49:     NEXT I
7360 B50:     SUBEND
7370 !
7380 !
7390   SUB Smigau(G(*),Pointer,Maxg,Maxi)
7400           OPTION BASE 1
7410           RAD
7420           Root=Pointer-1
7430 !        G(*) AND POINTER ARE USED HERE TO SIMULATE THE PASSING OF ARRAYS
AS PARAMETERS IN FORTRAN
7440           DIM P(30,30)
7450 ! C
7460 ! C     THIS ROUTINE CONVERTS A (MAXG,MAXG) ARRAY OF SPHERICAL HARMONIC
7470 ! C     COEFFICIENTS, STORED IN AN ARRAY DIMENSIONED (MAXI,MAXI),
7480 ! C     FROM SCHMIDT-NORMALIZED TO GAUSS-NORMALIZED (MAIN ENTRY), OR
7490 ! C     FROM GAUSS-NORMALIZED TO SCHMIDT-NORMALIZED (GAUSMI ENTRY).
7500 ! C
7510 ! C
7520          READ New,Max
7530          DATA    0,  30
7540          Next=1
7550 D1:      IF New<>0 THEN D10
7560          New=1
7570          P(1,1)=0
7580          P(1,2)=1
7590          P(2,2)=1
7600          FOR I=3 TO Max
7610          H=I-1
7620          P(I,I)=P(I-1,I-1)*SQR(1-.5/H)
7630          P(1,I)=P(1,I-1)*(2-1/H)
7640          H=H-1
7650          Hh=H^2
7660          FOR J=I TO Max
7670          F=J-1
7680          P(I-1,J)=P(I-1,J-1)*(F+F-1)/SQR(F*F-Hh)
7690 D3:      NEXT J
7700          NEXT I
7710          FOR I=2 TO Max
7720          FOR J=I TO Max
7730          P(J,I-1)=P(I,J)
7740          NEXT J
7750          NEXT I
7760 D10:     IF Next=2 THEN D21
7770 D11:     FOR J=1 TO Maxg
7780          K=(J-1)*Maxi+Root
7790          FOR I=1 TO Maxg
7800          G(I+K)=G(I+K)*P(I,J)
7810 D12:     NEXT I
7820          NEXT J
```

```
7830          SUBEXIT
7840 D21:     FOR J=1 TO Maxg
7850          K=(J-1)*Maxi+Root
7860          FOR I=1 TO Maxg
7870          Pij=P(I,J)
7880          IF Pij=0 THEN D22
7890          G(I+K)=G(I+K)/Pij
7900 D22:     NEXT I
7910          NEXT J
7920          SUBEXIT
7930 !            ENTRY  GAUSMI
7940 ! C     *                ( G, MAXG, MAXI )                                C
 OUT
7950          Next=2
7960          GOTO D1
7970          SUBEND
7980 !
7990 !
8000          DEF FNAtan2(Y,X)
8010 !        EQUIVALENT OF THE ATAN2 FUNCTION IN FORTRAN
8020          RAD
8030          IF X=0 THEN Vert
8040          Ang=ATN(Y/X)
8050          IF X>0 THEN RETURN Ang
8060          IF Y<0 THEN Q3
8070          Ang=Ang+PI
8080          RETURN Ang
8090 Q3:      Ang=Ang-PI
8100          RETURN Ang
8110 Vert:    IF Y<0 THEN Down
8120          Ang=PI/2
8130          RETURN Ang
8140 Down:    Ang=-PI/2
8150          RETURN Ang
8160          FNEND
```

Program DXPRO, Sample Run

DXPRO is the program that takes DXGET files of raw data and produces velocity profiles on files and as plots. The algorithms are described in Section III.B.2.

DXPRO is usually run with 10 probe revolutions per average and with 5 revolutions between each average. The probe calibrations are usually pre-stored in the XCAL:T15 file but can be entered by hand. DXPRO can search the XCAL:T15 file by probe number or drop number. The earth's magnetic field components must be entered with the calibration.

DXPRO will use the HP 9845T internal graphics option or an HP 9872A or HP 9872S plotter.

The following pages show the operator input and program output. The program listing follows.

```
DXPROZ                81:04:07:18:18:47
INPUT FILE NO.  1 ? (CLEAR TO TERMINATE)

620RD
EDIT COMMENTS
11:10:04:27:40 INTENSIVE SURVEY HEADING 270
NUMBER OF SCANS IN EACH AVERAGING WINDOW ?
10
STEPPING INCREMENT?
5
EDIT calibration file name. (BLANK TO ENTER CAL BY HAND)
XCAL  :T15
XTVP SERIAL NO. ? (ZERO TO SEARCH BY DROP NO.)
871
READING XCAL  :T15
EDIT:  Probe  Mod  Gcc Gcor   Gef Evco Cvco Drop   Fh   Fz
500  !   871    6 3628 1838 25230 1001 1000  620 .204-.490
OUTPUT FILE NAME?
620P
INPUT FILE NO.  2 ? (CLEAR TO TERMINATE)


PLOTTER ? (0=NONE, 1=GRAPHICS, 2=9872A, 3=9872S)
3
LOOKING FOR PF ON
LAUNCH-TIME=          11:10:04:27:52       12.2378              ISCAN= 98
DOWN-TIME=            11:10:04:29:06       86.24273             ISCAN= 673
PROCESSING FILE  1 . IFILE=620RD, OFILE=620P
   Z  Temp      U      V     W Rotf Area    Uw Vc0a Zcdp   Ve0a  Ve0p Fefb Fccb Ver
  -7 10.18  33.5  12.4 -454 5.23  882    94    59 -7.6   4.36 118.3 2453 450329.9
 -11 10.18  28.4    .1 -454 6.27  798    94    64 -8.3   4.85 113.9 2438 4505 9.0
 -15 10.18  44.0 -12.3 -454 6.60  771    94    65 -6.8   5.69 118.1 2477 4505 1.3
 -18 10.18  39.8 -18.4 -454 6.75  767    94    66 -6.5   5.90 114.9 2465 4504 1.1
 -21 10.18  32.9 -22.5 -454 6.83  767    94    67 -6.3   5.98 111.1 2485 4504 1.0
 -24 10.18  26.2 -22.0 -454 6.90  763    94    67 -6.5   5.88 108.2 2498 4504 1.1
```

-28	10.18	20.4	-19.5	-454	6.97	761	94	68	-6.5	5.70	105.7	2498	4504	.9
-31	10.18	16.2	-15.7	-454	7.00	764	94	69	-6.2	5.48	103.6	2497	4505	.9
-34	10.18	15.4	-9.9	-453	7.01	761	94	68	-6.2	5.19	103.6	2501	4505	.7
-37	10.18	16.4	-5.4	-453	6.99	759	94	68	-6.1	4.97	104.5	2501	4504	.6
-41	10.18	18.9	-1.7	-453	6.99	753	94	67	-6.3	4.82	106.4	2503	4505	.5
-44	10.17	21.3	-.6	-453	6.99	752	94	67	-6.2	4.78	107.9	2504	4504	.5
-47	10.18	24.0	-2.8	-453	6.96	750	94	67	-6.0	4.92	108.9	2505	4504	.7
-50	10.17	26.0	-4.7	-453	6.93	749	94	67	-6.1	5.04	109.9	2506	4504	.5
-54	10.17	26.3	-6.5	-453	6.92	746	94	66	-6.1	5.12	109.8	2506	4504	.5
-57	10.17	25.2	-8.9	-453	6.92	745	94	66	-6.1	5.23	108.9	2506	4504	.3
-60	10.06	24.6	-10.4	-453	6.90	741	94	66	-5.9	5.29	108.2	2506	4504	.6
-64	9.27	19.1	-16.5	-453	6.88	751	94	66	-6.2	5.53	105.0	2507	4504	1.6
-67	8.17	6.0	-26.6	-453	6.93	792	94	70	-6.5	5.95	98.3	2506	4504	1.7
-70	7.55	-4.2	-31.0	-452	6.98	822	94	74	-6.3	6.17	93.3	2506	4504	1.0
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver
-73	7.18	-10.2	-36.7	-452	6.98	846	94	76	-6.1	6.46	90.6	2506	4504	.8
-77	6.79	-14.0	-39.5	-452	6.94	859	94	76	-6.0	6.62	88.9	2506	4504	.5
-80	6.59	-16.0	-38.5	-452	6.90	855	94	76	-6.0	6.58	88.1	2506	4504	.3
-83	6.48	-16.1	-35.1	-452	6.89	840	94	74	-6.0	6.41	87.8	2505	4504	.5
-86	6.43	-16.2	-28.6	-452	6.86	815	94	72	-5.7	6.09	87.1	2505	4504	.4
-90	6.39	-14.6	-23.6	-452	6.84	793	94	69	-6.0	5.84	87.8	2505	4503	.6
-93	6.33	-13.0	-16.1	-452	6.82	764	94	67	-6.0	5.46	88.1	2505	4503	.6
-96	6.26	-11.8	-10.1	-452	6.81	737	94	64	-5.9	5.16	88.4	2505	4503	.4
-100	6.16	-10.2	-6.6	-452	6.82	722	94	63	-5.9	4.97	89.1	2505	4503	.5
-103	6.12	-8.7	-8.4	-451	6.80	723	93	63	-5.9	5.05	90.0	2505	4503	.6
-106	6.09	-8.9	-12.4	-451	6.77	733	93	64	-6.0	5.25	90.1	2505	4503	.4
-110	6.02	-9.0	-10.0	-451	6.78	729	93	63	-6.1	5.13	90.1	2505	4502	.8
-113	5.92	-4.2	-7.3	-451	6.81	718	93	63	-6.0	4.98	92.6	2505	4502	.9
-116	5.86	-.6	-3.6	-451	6.81	704	93	62	-5.8	4.79	94.4	2505	4503	1.0
-120	5.87	2.6	8.3	-451	6.80	669	93	58	-6.0	4.21	96.7	2505	4503	1.0
-123	5.83	5.2	15.2	-451	6.81	648	93	57	-6.2	3.87	98.9	2505	4502	.8
-126	5.81	7.5	18.6	-451	6.82	648	93	57	-6.1	3.71	100.8	2505	4502	.7
-130	5.77	5.6	19.2	-451	6.82	656	93	57	-6.2	3.67	99.5	2505	4502	.5
-133	5.73	4.1	17.4	-451	6.80	679	93	59	-6.1	3.76	98.1	2505	4502	.3
-136	5.72	6.1	14.6	-450	6.78	700	93	61	-6.1	3.90	99.4	2505	4502	.6
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver
-139	5.72	6.3	7.8	-450	6.78	726	93	63	-6.1	4.24	99.3	2505	4502	.5
-143	5.72	8.7	4.5	-450	6.78	742	93	64	-6.0	4.41	100.5	2505	4502	.6
-146	5.70	10.2	.6	-450	6.76	750	93	65	-5.9	4.61	101.1	2505	4502	.7
-149	5.67	9.5	-5.4	-450	6.75	766	93	66	-6.0	4.89	100.4	2505	4502	.6
-153	5.63	9.3	-10.2	-450	6.76	779	93	67	-6.1	5.13	100.1	2505	4502	.4
-156	5.60	9.3	-10.6	-450	6.77	775	93	67	-6.0	5.15	100.0	2505	4502	.4
-159	5.59	8.9	-7.1	-450	6.76	760	93	66	-5.8	4.98	99.9	2505	4502	.4
-163	5.59	9.4	-5.4	-450	6.74	751	93	65	-5.8	4.89	100.2	2505	4502	.3
-166	5.60	7.3	-3.8	-450	6.74	744	93	64	-5.9	4.80	99.2	2505	4502	.5
-169	5.61	5.5	-3.2	-449	6.76	742	93	64	-6.1	4.77	98.3	2505	4502	.3
-173	5.61	4.2	-3.0	-449	6.77	744	93	65	-5.9	4.75	97.4	2505	4502	.5
-176	5.58	2.3	-4.1	-449	6.75	751	93	65	-5.9	4.80	96.2	2505	4502	.4
-179	5.55	1.9	-4.5	-449	6.74	754	93	65	-6.0	4.82	96.0	2505	4502	.4
-183	5.52	1.6	-4.9	-449	6.75	757	93	65	-6.0	4.84	95.9	2505	4502	.3
-186	5.49	2.1	-5.0	-449	6.75	757	93	66	-5.9	4.85	96.1	2505	4502	.3
-189	5.45	2.3	-3.9	-449	6.74	753	93	65	-5.9	4.79	96.2	2505	4502	.3
-193	5.41	2.5	-3.5	-449	6.72	750	93	65	-6.0	4.77	96.4	2505	4501	.4
-196	5.37	2.8	-3.8	-449	6.73	751	93	65	-6.0	4.78	96.5	2504	4501	.4
-199	5.32	3.9	-1.6	-449	6.74	744	93	64	-5.8	4.67	97.1	2505	4502	.3
-203	5.28	3.9	.1	-448	6.73	736	93	63	-5.8	4.59	97.1	2505	4502	.3
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver

-206	5.24	4.3	.4	-448	6.71	737	93	63	-5.9	4.58	97.4	2505	4502	.3
-209	5.22	4.5	-1.1	-448	6.71	740	93	64	-6.0	4.65	97.7	2505	4502	.3
-213	5.17	5.9	-3.1	-448	6.74	744	93	64	-5.9	4.75	98.4	2504	4502	.3
-216	5.11	6.9	-1.9	-448	6.73	743	93	64	-5.7	4.69	98.8	2505	4502	.3
-219	5.05	7.6	-2.9	-448	6.70	745	93	64	-5.7	4.74	99.2	2504	4502	.4
-223	5.02	7.9	-4.9	-448	6.69	747	93	64	-5.9	4.84	99.4	2505	4502	.3
-226	5.01	8.3	-4.1	-448	6.71	745	93	64	-6.0	4.80	99.8	2505	4502	.4
-229	4.99	9.2	-2.5	-448	6.72	738	93	64	-5.9	4.73	100.3	2505	4502	.3
-233	4.97	9.0	-2.4	-448	6.70	736	93	63	-5.8	4.72	100.1	2505	4502	.3
-236	4.93	10.1	-3.3	-447	6.68	739	93	63	-6.0	4.77	100.9	2505	4502	.4
-239	4.89	11.8	-4.6	-447	6.70	739	93	63	-6.0	4.84	101.8	2505	4502	.4
-243	4.86	13.3	-3.4	-447	6.71	735	93	63	-5.8	4.79	102.6	2504	4502	.5
-246	4.84	13.8	-1.6	-447	6.69	728	93	62	-5.7	4.71	103.0	2505	4502	.4
-249	4.82	14.0	-1.7	-447	6.67	727	93	62	-5.9	4.71	103.2	2505	4502	.4
-253	4.81	14.4	-3.9	-447	6.68	735	93	63	-5.9	4.82	103.3	2505	4502	.3
-256	4.79	13.9	-4.4	-447	6.69	739	93	63	-5.9	4.84	103.0	2505	4502	.3
-260	4.76	14.1	-3.9	-447	6.69	739	93	63	-5.8	4.81	103.0	2505	4502	.3
-263	4.73	14.3	-3.7	-447	6.65	738	92	63	-5.6	4.81	103.0	2505	4502	.4
-266	4.70	14.2	-2.3	-447	6.64	736	92	63	-5.9	4.73	103.3	2504	4502	.4
-270	4.68	14.5	-2.4	-446	6.67	737	92	63	-6.1	4.74	103.7	2504	4502	.3
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver
-273	4.65	14.7	-3.2	-446	6.69	739	92	63	-6.0	4.78	103.7	2505	4502	.3
-276	4.61	13.8	-3.6	-446	6.67	743	92	64	-5.8	4.79	102.9	2504	4502	.4
-280	4.63	13.9	-4.0	-446	6.65	745	92	64	-5.7	4.81	102.8	2504	4502	.4
-283	4.63	13.4	-5.4	-446	6.66	746	92	64	-5.9	4.88	102.6	2505	4502	.3
-286	4.61	12.3	-6.5	-446	6.68	749	92	64	-5.8	4.92	101.9	2505	4502	.3
-290	4.57	11.7	-6.7	-446	6.66	752	92	64	-5.7	4.93	101.3	2504	4502	.3
-293	4.57	11.9	-6.1	-446	6.63	752	92	64	-5.7	4.90	101.5	2504	4502	.3
-296	4.56	11.2	-4.6	-446	6.63	746	92	63	-6.0	4.82	101.5	2504	4502	.4
-300	4.56	11.6	-4.0	-446	6.66	743	92	63	-6.1	4.79	101.8	2504	4502	.4
-303	4.55	12.5	-2.4	-445	6.66	740	92	63	-5.9	4.72	102.3	2504	4502	.3
-306	4.53	12.7	-1.1	-445	6.64	736	92	63	-5.8	4.66	102.5	2504	4502	.2
-310	4.49	11.4	-1.1	-445	6.63	737	92	63	-5.8	4.65	101.6	2504	4502	.3
-313	4.43	11.2	-1.0	-445	6.64	738	92	63	-5.9	4.64	101.6	2504	4502	.3
-316	4.42	12.7	.0	-445	6.66	736	92	63	-6.0	4.60	102.7	2504	4501	.4
-320	4.39	14.6	-.7	-445	6.64	738	92	63	-5.7	4.64	103.6	2504	4501	.3
-323	4.36	15.1	-2.1	-445	6.61	740	92	63	-5.7	4.72	103.7	2504	4501	.4
-327	4.33	14.3	-4.4	-445	6.62	746	92	63	-6.1	4.82	103.4	2504	4501	.5
-330	4.32	13.3	-5.4	-445	6.64	750	92	64	-5.9	4.86	102.5	2504	4501	.5
-333	4.31	12.5	-3.0	-444	6.64	744	92	63	-5.7	4.74	102.1	2504	4502	.4
-337	4.29	11.8	.1	-444	6.61	734	92	62	-5.6	4.58	101.9	2504	4501	.4
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver
-340	4.28	11.9	-.0	-444	6.59	734	92	62	-5.9	4.59	102.1	2504	4501	.3
-343	4.29	11.6	-.9	-444	6.61	740	92	63	-5.8	4.62	101.9	2504	4501	.2
-347	4.28	11.0	-.5	-444	6.62	742	92	63	-5.9	4.60	101.6	2504	4502	.3
-350	4.26	11.7	1.0	-444	6.60	738	92	62	-5.7	4.53	101.9	2504	4502	.3
-353	4.23	11.8	.1	-444	6.59	739	92	62	-5.7	4.58	101.9	2504	4501	.3
-357	4.22	10.4	-.5	-444	6.60	744	92	63	-5.9	4.60	101.3	2504	4501	.4
-360	4.21	9.1	-1.5	-444	6.61	748	92	63	-5.9	4.64	100.3	2504	4501	.4
-363	4.21	7.4	-1.7	-444	6.61	751	92	64	-5.8	4.64	99.3	2504	4502	.3
-367	4.20	6.2	-2.6	-443	6.59	754	92	64	-5.7	4.68	98.3	2504	4502	.3
-370	4.20	6.3	-3.9	-443	6.58	758	92	64	-5.7	4.74	98.3	2504	4502	.3
-374	4.18	6.2	-2.7	-443	6.59	758	92	64	-5.7	4.68	98.4	2504	4502	.4
-377	4.17	6.4	-.2	-443	6.60	751	92	64	-5.7	4.55	98.6	2504	4501	.4
-380	4.17	6.7	1.0	-443	6.58	747	92	63	-5.6	4.50	98.7	2504	4501	.3
-384	4.16	6.2	1.6	-443	6.57	743	92	63	-5.8	4.47	98.6	2504	4501	.3
-387	4.15	6.7	2.4	-443	6.58	741	92	62	-5.8	4.42	98.9	2504	4502	.3

-390	4.15	7.2	2.5	-443	6.60	741	92	63	-5.7	4.42	99.2	2504	4502	.3
-394	4.14	7.7	2.7	-443	6.59	739	92	62	-5.7	4.41	99.5	2504	4501	.3
-397	4.14	7.3	1.9	-443	6.57	740	92	62	-5.6	4.45	99.2	2504	4501	.5
-401	4.13	5.8	.1	-442	6.56	746	92	63	-5.8	4.53	98.3	2504	4502	.5
-404	4.12	6.4	-1.3	-442	6.58	753	92	63	-5.8	4.61	98.6	2504	4502	.4
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver
-407	4.10	5.9	-1.2	-442	6.58	752	92	63	-5.7	4.60	98.2	2504	4502	.3
-411	4.09	6.9	-1.0	-442	6.57	748	92	63	-5.7	4.59	98.8	2504	4502	.3
-414	4.08	7.2	-2.0	-442	6.56	750	92	63	-5.8	4.64	99.1	2504	4501	.4
-417	4.08	6.3	-2.7	-442	6.58	751	92	63	-5.9	4.67	98.6	2504	4501	.3
-421	4.07	6.9	-3.1	-442	6.59	751	92	63	-5.8	4.69	98.8	2504	4502	.4
-424	4.07	6.8	-2.6	-442	6.58	749	91	63	-5.6	4.66	98.6	2504	4502	.4
-427	4.07	6.3	-3.0	-442	6.55	747	91	63	-5.6	4.68	98.3	2504	4502	.4
-431	4.07	5.6	-3.5	-442	6.55	748	91	63	-5.8	4.70	98.0	2504	4501	.3
-434	4.06	6.1	-4.9	-441	6.57	750	91	63	-5.8	4.77	98.4	2504	4501	.4
-438	4.05	5.6	-6.5	-441	6.56	753	91	63	-5.6	4.85	97.8	2504	4502	.4
-441	4.03	5.2	-6.1	-441	6.54	750	91	63	-5.6	4.82	97.5	2504	4501	.4
-444	4.02	5.3	-4.7	-441	6.54	745	91	62	-5.8	4.75	97.9	2504	4501	.4
-448	4.02	4.7	-3.5	-441	6.56	742	91	62	-6.0	4.69	97.7	2504	4502	.3
-451	4.01	4.0	-3.7	-441	6.58	742	91	62	-5.9	4.70	97.2	2504	4502	.3
-454	4.01	4.6	-4.6	-441	6.56	744	91	63	-5.7	4.75	97.3	2504	4502	.3
-458	4.01	5.2	-3.5	-441	6.55	742	91	62	-5.7	4.69	97.7	2504	4502	.3
-461	4.01	5.4	-5.3	-441	6.55	745	91	62	-5.7	4.78	97.8	2504	4502	.3
-464	4.01	4.5	-6.1	-440	6.55	749	91	63	-5.9	4.81	97.4	2504	4502	.4
-468	4.00	4.7	-8.1	-440	6.55	752	91	63	-5.7	4.91	97.3	2504	4502	.4
-471	4.00	4.3	-7.6	-440	6.53	751	91	63	-5.6	4.89	96.9	2504	4502	.4
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver
-475	3.99	4.0	-6.3	-440	6.51	748	91	62	-5.8	4.82	97.0	2504	4502	.4
-478	3.99	4.4	-4.9	-440	6.54	743	91	62	-5.8	4.75	97.4	2504	4502	.3
-481	3.98	6.1	-3.9	-440	6.55	739	91	62	-5.7	4.70	98.3	2504	4502	.4
-485	3.98	6.2	-3.1	-440	6.54	736	91	62	-5.7	4.67	98.4	2504	4502	.3
-488	3.97	5.4	-4.7	-440	6.52	739	91	62	-5.6	4.74	97.7	2504	4502	.3
-491	3.97	5.2	-6.9	-440	6.52	745	91	62	-5.8	4.85	97.7	2504	4502	.3
-495	3.97	4.7	-8.4	-440	6.54	750	91	63	-5.9	4.92	97.5	2504	4502	.2
-498	3.96	4.8	-10.2	-439	6.54	753	91	63	-5.7	5.01	97.3	2504	4502	.3
-501	3.96	4.3	-9.6	-439	6.51	753	91	63	-5.5	4.98	96.8	2504	4502	.3
-505	3.95	4.5	-10.6	-439	6.50	753	91	63	-5.6	5.02	97.0	2504	4502	.4
-508	3.94	4.8	-14.0	-439	6.52	759	91	63	-5.8	5.19	97.3	2504	4501	.4
-512	3.94	4.7	-12.1	-439	6.53	754	91	63	-5.7	5.10	97.2	2504	4501	.4
-515	3.93	5.3	-10.5	-439	6.52	746	91	62	-5.6	5.02	97.4	2504	4502	.3
-518	3.92	6.6	-9.4	-439	6.50	741	91	62	-5.5	4.97	98.2	2504	4502	.3
-522	3.91	7.9	-9.8	-439	6.50	738	91	61	-5.7	4.99	99.0	2504	4502	.3
-525	3.91	8.2	-10.5	-439	6.51	739	91	62	-5.7	5.03	99.2	2504	4502	.2
-528	3.89	8.8	-10.1	-439	6.52	736	91	61	-5.7	5.01	99.5	2504	4502	.2
-532	3.88	8.0	-9.0	-438	6.49	735	91	61	-5.5	4.95	99.0	2504	4502	.2
-535	3.88	8.1	-8.0	-438	6.49	733	91	61	-5.6	4.90	99.2	2504	4502	.2
-539	3.87	7.9	-9.2	-438	6.51	736	91	61	-5.8	4.96	99.2	2505	4502	.3
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver
-542	3.86	7.6	-8.1	-438	6.53	735	91	62	-5.8	4.90	99.0	2504	4502	.3
-545	3.86	8.9	-8.7	-438	6.51	738	91	62	-5.6	4.93	99.5	2504	4502	.3
-549	3.85	9.4	-8.6	-438	6.48	741	91	62	-5.6	4.93	99.8	2504	4502	.3
-552	3.85	9.2	-8.9	-438	6.49	741	91	62	-5.7	4.94	99.9	2504	4502	.4
-555	3.84	8.3	-9.7	-438	6.51	742	91	62	-5.8	4.98	99.4	2504	4502	.3
-559	3.83	7.7	-10.4	-438	6.50	744	91	62	-5.6	5.01	98.9	2504	4502	.3
-562	3.82	7.3	-10.1	-437	6.47	745	91	62	-5.6	4.99	98.6	2504	4502	.3
-565	3.81	6.9	-8.7	-437	6.48	743	91	62	-5.8	4.92	98.6	2504	4502	.4
-569	3.81	7.1	-8.7	-437	6.50	743	91	62	-5.8	4.92	98.7	2504	4501	.4

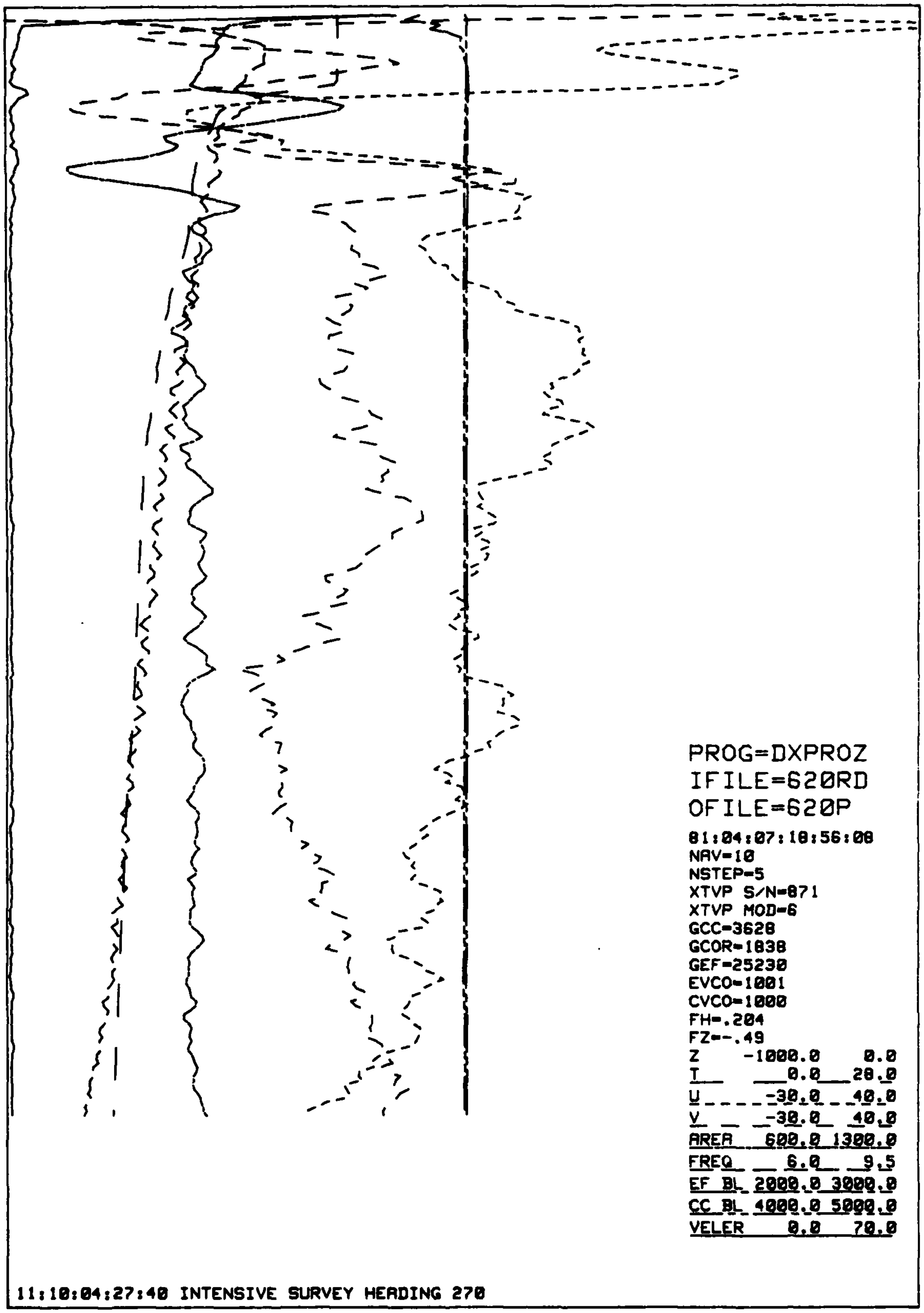
-572	3.79	5.9	-9.2	-437	6.49	746	91	62	-5.6	4.94	97.8	2504	4502	.3
-576	3.78	5.5	-9.4	-437	6.47	750	91	62	-5.6	4.95	97.5	2504	4501	.3
-579	3.77	4.0	-9.6	-437	6.47	751	90	62	-5.7	4.95	96.8	2504	4502	.3
-582	3.76	3.4	-9.9	-437	6.48	751	90	62	-5.7	4.96	96.5	2504	4502	.3
-586	3.76	2.8	-9.3	-437	6.49	752	90	63	-5.6	4.93	96.1	2504	4502	.3
-589	3.75	3.9	-9.8	-437	6.47	750	90	62	-5.6	4.96	96.6	2504	4501	.4
-592	3.74	4.3	-9.6	-437	6.46	747	90	62	-5.8	4.95	97.1	2504	4501	.4
-596	3.74	3.7	-8.9	-436	6.48	745	90	62	-5.8	4.91	96.8	2504	4501	.3
-599	3.72	4.8	-8.6	-436	6.48	743	90	62	-5.5	4.90	97.1	2504	4501	.4
-603	3.71	5.1	-8.9	-436	6.46	743	90	62	-5.5	4.91	97.3	2504	4501	.4
-606	3.71	4.9	-8.5	-436	6.46	741	90	61	-5.6	4.89	97.3	2504	4501	.4
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver
-609	3.70	4.5	-7.4	-436	6.47	739	90	61	-5.7	4.83	97.2	2504	4501	.4
-613	3.69	5.3	-8.1	-436	6.47	741	90	61	-5.6	4.87	97.6	2504	4501	.3
-616	3.68	4.9	-9.2	-436	6.46	745	90	62	-5.4	4.92	97.1	2504	4501	.4
-619	3.67	4.1	-9.8	-436	6.44	747	90	62	-5.6	4.95	96.7	2504	4501	.5
-623	3.66	3.2	-8.7	-436	6.46	747	90	62	-5.7	4.89	96.5	2504	4501	.4
-626	3.66	2.6	-8.0	-435	6.46	745	90	62	-5.5	4.86	95.9	2504	4501	.4
-630	3.65	2.2	-8.2	-435	6.45	746	90	62	-5.5	4.87	95.7	2504	4501	.2
-633	3.64	1.8	-8.3	-435	6.44	746	90	62	-5.6	4.86	95.5	2504	4501	.2
-636	3.64	2.3	-8.1	-435	6.46	746	90	62	-5.8	4.86	96.0	2504	4501	.3
-640	3.63	1.8	-7.6	-435	6.47	744	90	62	-5.6	4.83	95.5	2504	4501	.3
-643	3.62	1.4	-6.7	-435	6.45	744	90	62	-5.5	4.78	95.2	2504	4501	.3
-646	3.61	.9	-7.6	-435	6.44	747	90	62	-5.6	4.83	95.0	2504	4501	.3
-650	3.61	.4	-6.6	-435	6.45	745	90	62	-5.7	4.77	94.8	2504	4501	.3
-653	3.60	.7	-5.5	-435	6.46	742	90	61	-5.7	4.72	94.9	2504	4501	.3
-657	3.59	1.3	-5.6	-435	6.44	741	90	61	-5.5	4.73	95.2	2504	4502	.3
-660	3.59	1.1	-6.4	-434	6.44	742	90	61	-5.6	4.77	95.1	2504	4502	.3
-663	3.59	1.4	-5.5	-434	6.45	745	90	62	-5.6	4.72	95.3	2504	4501	.3
-667	3.58	1.4	-4.8	-434	6.45	745	90	62	-5.6	4.68	95.3	2504	4501	.2
-670	3.58	1.0	-3.8	-434	6.43	739	90	61	-5.6	4.63	95.1	2504	4501	.2
-673	3.57	1.6	-5.3	-434	6.44	741	90	61	-5.7	4.71	95.5	2504	4501	.3
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver
-677	3.56	2.6	-5.6	-434	6.46	744	90	62	-5.7	4.72	96.1	2504	4501	.3
-680	3.56	3.3	-5.5	-434	6.45	742	90	61	-5.4	4.72	96.2	2504	4501	.3
-684	3.56	3.1	-5.2	-434	6.42	742	90	61	-5.5	4.70	96.2	2504	4501	.4
-687	3.56	3.4	-6.6	-434	6.43	743	90	61	-5.7	4.77	96.6	2504	4501	.3
-690	3.55	3.0	-6.2	-434	6.44	744	90	61	-5.6	4.75	96.2	2504	4501	.3
-694	3.54	2.9	-4.9	-433	6.42	741	90	61	-5.3	4.68	95.9	2504	4501	.2
-697	3.54	2.0	-4.2	-433	6.40	741	90	61	-5.6	4.65	95.7	2504	4501	.2
-700	3.53	1.8	-3.3	-433	6.42	741	90	61	-5.8	4.60	95.7	2504	4501	.2
-704	3.52	2.3	-3.1	-433	6.43	740	90	61	-5.5	4.59	95.8	2504	4501	.2
-707	3.51	2.1	-3.7	-433	6.40	742	90	61	-5.4	4.61	95.5	2504	4501	.4
-711	3.51	.1	-4.3	-433	6.42	746	90	61	-5.6	4.64	94.5	2504	4502	.4
-714	3.50	.0	-4.1	-433	6.43	750	90	62	-5.5	4.63	94.4	2504	4502	.3
-717	3.49	-.8	-4.8	-433	6.41	751	90	62	-5.4	4.67	93.8	2504	4502	.4
-721	3.49	-.4	-5.5	-433	6.41	749	90	62	-5.6	4.70	94.2	2504	4502	.3
-724	3.49	-.4	-5.4	-432	6.42	745	90	61	-5.6	4.69	94.2	2504	4502	.4
-727	3.48	-.3	-3.4	-432	6.41	741	90	61	-5.4	4.59	94.1	2504	4502	.4
-731	3.47	.7	-2.9	-432	6.40	739	90	61	-5.6	4.57	94.9	2504	4501	.2
-734	3.46	1.4	-3.1	-432	6.41	740	89	61	-5.7	4.58	95.4	2504	4501	.3
-737	3.46	2.0	-3.1	-432	6.42	739	89	61	-5.6	4.58	95.7	2504	4501	.3
-741	3.45	2.3	-3.0	-432	6.41	740	89	61	-5.5	4.57	95.7	2504	4502	.3
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver
-744	3.45	3.0	-3.0	-432	6.40	740	89	61	-5.6	4.57	96.3	2504	450[illegible]	.2
-748	3.45	3.5	-2.2	-432	6.41	738	89	61	-5.6	4.53	96.6	2504	4502	.3
-751	3.44	2.7	-2.4	-432	6.40	738	89	61	-5.5	4.54	96.0	2504	4501	.3
-754	3.43	2.0	-2.5	-432	6.39	740	89	61	-5.6	4.54	95.6	2504	4501	.3

-758	3.43	1.8	-1.8	-431	6.39	741	89	61	-5.6	4.51	95.6	2504	4502	.5
-761	3.42	.9	-2.1	-431	6.39	742	89	61	-5.5	4.52	94.9	2504	4501	.5
-764	3.42	.9	-3.5	-431	6.37	745	89	61	-5.5	4.59	94.9	2504	4501	.4
-768	3.41	.8	-3.2	-431	6.37	745	89	61	-5.5	4.57	94.8	2504	4502	.4
-771	3.41	.3	-1.8	-431	6.39	741	89	61	-5.5	4.50	94.5	2504	4502	.3
-775	3.41	.4	-.8	-431	6.38	736	89	60	-5.6	4.45	94.7	2504	4502	.3
-778	3.40	.9	-.7	-431	6.38	735	89	60	-5.6	4.44	95.0	2504	4502	.3
-781	3.39	1.2	-1.3	-431	6.37	739	89	60	-5.5	4.47	95.1	2504	4502	.3
-785	3.38	1.7	-1.7	-431	6.36	742	89	60	-5.4	4.49	95.3	2504	4502	.3
-788	3.37	1.8	-1.4	-430	6.35	740	89	60	-5.5	4.48	95.5	2504	4502	.3
-792	3.37	1.6	-1.9	-430	6.36	740	89	60	-5.6	4.50	95.4	2505	4502	.3
-795	3.36	1.4	-1.2	-430	6.35	742	89	60	-5.3	4.46	95.0	2504	4502	.3
-798	3.35	1.2	-.5	-430	6.36	740	89	60	-5.5	4.43	95.1	2505	4502	.5
-802	3.34	-.1	-.3	-430	6.36	739	89	60	-5.5	4.42	94.2	2504	4502	.5
-805	3.34	-1.2	-.3	-430	6.35	741	89	60	-5.4	4.42	93.5	2504	4502	.4
-808	3.33	-1.7	-.4	-430	6.34	743	89	60	-5.6	4.42	93.3	2504	4502	.3
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver
-812	3.33	-2.0	-.3	-430	6.35	744	89	61	-5.6	4.41	93.1	2504	4502	.3
-815	3.33	-1.9	-1.3	-430	6.33	746	89	61	-5.3	4.46	93.0	2504	4502	.3
-819	3.32	-3.0	-.9	-429	6.33	746	89	60	-5.5	4.44	92.4	2504	4502	.3
-822	3.32	-3.0	.4	-429	6.33	743	89	60	-5.7	4.38	92.5	2504	4502	.3
-825	3.31	-2.7	.1	-429	6.32	743	89	60	-5.5	4.39	92.6	2504	4502	.3
-829	3.31	-4.1	.0	-429	6.32	743	89	60	-5.6	4.40	91.7	2504	4502	.4
-832	3.30	-3.9	1.1	-429	6.32	744	89	60	-5.4	4.34	91.7	2504	4502	.4
-836	3.29	-3.7	.1	-429	6.31	746	89	60	-5.4	4.39	91.8	2505	4502	.4
-839	3.28	-3.9	-.4	-429	6.32	749	89	61	-5.5	4.42	91.8	2504	4502	.3
-842	3.28	-5.4	-.8	-429	6.31	749	89	61	-5.4	4.44	90.8	2504	4502	.3
-846	3.27	-6.1	-1.5	-429	6.30	751	89	61	-5.4	4.47	90.4	2504	4502	.3
-849	3.27	-6.9	-1.7	-429	6.30	751	89	61	-5.5	4.49	90.0	2504	4502	.3
-853	3.27	-7.4	-2.0	-428	6.30	753	89	61	-5.4	4.50	89.6	2504	4502	.4
-856	3.26	-7.5	-2.7	-428	6.29	753	89	61	-5.5	4.53	89.6	2505	4502	.4
-859	1.78	77.2	-3.9	-428	6.23	1612	89	129	72.9	5.96	55.7	2450	4507	

282.997415541 2D.D

-862 -1.98 347.2-259.3 -428 7.1610727   89 985
-219.813728993 3D.D
24.29 -6.2 2450 4484
425.722796875 2D.D

MEAN AREA= 745 cm^2
Z-1000 0
ENTER NEW PLOT LIMITS: PLO, PHI


PROG=DXPROZ
IFILE=620RD
OFILE=620P
81:04:07:10:56:08
NAV=10
NSTEP=5
XTVP S/N=871
XTVP MOD=6
GCC=3620
GCOR=1838
GEF=25230
EVCO=1001
CVCO=1000
FH=.204
FZ=-.49
Z -1000.0 0.0
T 0.0 20.0
U -30.0 40.0
V -30.0 40.0
AREA 600.0 1300.0
FREQ 6.0 9.5
EF BL 2000.0 3000.0
CC BL 4000.0 5000.0
VELER 0.0 70.0
11:10:04:27:40 INTENSIVE SURVEY HEADING 270

Listing of DXPRO

```
10     Progrev$="DXPROZ"  ! PROGRAM REVISION
20     Year=81
30     !
40     ! DXPRO  .. DEC 19 79. DIGITAL XTVP RCVR PROCESSING (see outline below)
50     ! DXPROB .. DEC 21 79. BARTLETT WINDOWS; INSTANTANEOUS NORMALIZATION.
60     ! DXPROC .. JAN 13 80. CORRECTED I & Q OF EF & CC FOR DIFF UP & DOWN COUNT
 TIMES
70     ! DXPROD .. JAN 14 80. ALLOW FOR RCVR HICCUPS AND DE-GLITCH I&Q
80     ! DXPROE .. JAN 15 80. FORCE TIME TO INCREASE AFTER PF COMES ON FOR 5 TURN
S
90     ! DXPROF .. JAN 16 80. PROCESS ONLY.  TO GET DATA USE DXGET.
100    ! DXPROG .. JAN 17 80. INTERPOLATE TO EQUALLY SPACED DEPTH AND OUTPUT FILE
110    ! DXPROH .. JAN 25 80. MORE INFO TO GET TO SCAN WHERE PROBE FALLS
120    ! DXPROI .. MAR 9 80. PROCESS BASELINE INFO. SIGN OF Q FROM RVCR CHANGED.
130    ! DXPROJ .. MAR 11 80. PLOT EF&CC BL.
140    ! DXPROK .. MAR 19 80. MORE TESTS.
150    ! DXPROL .. MAR 24 80. PLOT  BL AVGS AND STD DEV
160    ! DXPROM .. MAR 25 80. PLOT RMSERR
170    ! DXPRON .. MAR 25 80. RMSERR SHOWS DIFF BETWEEN ERRCOR=3 AND ERRCOR=1
180    ! DXPROP .. MAR 28 80. RMSERR FROM RMS OF DATA.
190    ! DXPROR .. APR 29 80. MODIFIED TO OUTPUT NEW FILE FORMAT AND USE GRAPHICS
200    ! DXPROS .. MAY 6 80.  SPEEDED UP DXPROR BY ONLY CORRECTING NEW DATA
210    ! DXPROT .. JUN 17 80.  CHANGED RMSERR TO VELERR=RMSERR/SQR(NAV)
220    ! DXPROV .. JUL 31 80. ADDED "BATCH" CAPABILITY.
230    ! DXPROW .. AUG 5 80. ADDED 9872S LOGIC FOR BATCH.
240    !         .. OCT 31 80. REMOVED PAUSE BEFORE PLOTTING ON 9872A.
250    !            AND CHANGED CAL FILE TO BE ON :T15
260    ! DXPROX .. NOV 19 80. FIXED PROBLEMS WITH COMPENSATION
270    !            DXPROW AND PREVIOUS DID NOT HANDLE PROBE PHASES CORRECTLY
280    !            THE PROBE PHASE VS FREQ COEFFICIENTS ARE ALSO ADDED.
290    !
300    ! DXPROY .. JAN 28 81. ADDED COMMENTS. JHD.
310    ! DXPROZ .. MAR 31 81. ADDED D'ASARO TILT CORRECTION. JHD.
320    !
330    ! OUTLINE ..........................................................
340    ! Initialization
350    !    - print program name ,revision and run time
360    !    - dimension arrays
370    !    - read in processing parameters for up to 100 drops; terminate when
380    !      an input file name is blank.
390    !    - get parameter file name with probe gain calibrations.
400    !    - use serial number of drop i.d. to search parameter file for gains.
410    !    - calibration string can be editted.
420    !    - must add the earth's magnetic field if not in file
430    !    - the plotter choice allows the 9872A only when one file is processed
440    ! Drop loop: repeats once per drop
450    !    - some constants are preset to reduce run time.
460    ! Main Processing Loop.
470    !    - repeats once each NAV-long averaging window.
480    !    - For NAV=10, NSTEP=5 this loop repeats about 300 times.
490    !    - read raw input data keeping in sync with the sync word (7777 hex)
500    !    - look for beginning of drop by examining status word:
510    !      1. received carriers
520    !      2. probe falling bit (PF)
530    !    - probe depth is based on the time from the PF bit turns on.
```

```
540    !   - for each new raw data scan the baseline error correction is
550    !     applied to I and Q and the scan is appended to the Dbuf(*) array.
560    !   - old scans are pushed off end of Dbuf(*) array
570    !   - form  Dav(*) array with  weighted averages of Dbuf(*).
580    !   - in-phase and quadrature-phase probe carrier frequencies are computed
590    !   - real and imaginary input voltages to probe are computed.
600    !   - U and V velocity component estimates are computed.  tilt correction
610    !     is done in next loop as mean area is needed.
620    !   - each output scan is stored in Dout(*) array.
630    ! Correct the north component for North-South tilt errors
640    !   - need mean area
650    !   - fix the Dout(*) array
660    ! Write Data in Dout(*) to File.
670    !   - stanardized format with labels
680    ! Plot Data on 9872A, 9872S, or GRAPHICS screen.
690    !   - the 9872S handles multiple plots
700    !   - keep to 8.5 by 11 inch plots
710    !   - all graphs on one sheet in multiple colors
720    ! Repeat drop loop
730    !
740    Printer=0
750    PRINTER IS Printer
760    !
770    OUTPUT 9;"R"         ! SETUP TO GET REAL-TIME FROM CLOCK
780    ENTER 9;Runtime$     ! GET IT
790    Runtime$=VAL$(Year)&":"&Runtime$
800    PRINT Progrev$,Runtime$
810    !
820    OPTION BASE 1        ! STARTS ARRAYS AT 1 INSTEAD OF DEFAULT 0
830    OVERLAP              ! RUN HP-9845 PROCESSORS SO I/O OVERLAPS CPU
840    DEG                  ! TRIG FUNCTIONS USE DEGREES INSTEAD OF RADIANS
850    !
860    DIM Comment$[160]    ! COMMENTS FROM/TO FILES
870    DIM Var$(9)          ! OUTPUT FILE VARIABLE NAMES
880    DIM String$[160]     ! USED TO READ PARAMETER FILE
890    !
900    SHORT Din(2:11)      ! INPUT DATA BUFFER READS 10 VALUES PER READ
910    SHORT Dbuf(52,2:10)! PUSH-DOWN INPUT BUFFER WITH EXTRA SCAN AT EACH END
920                         ! NEEDED FOR BASELINE ERROR CORRECTION.
930    SHORT Wt(50)         ! BARTLETT FILTER WEIGHTS APPLIED TO INPUT DATA
940    SHORT Dav(2:10)      ! FOR DOT PRODUCT OF DBUF AND WT
950    !
960    SHORT Phi(9)         ! PLOTTER HIGH LIMITS
970    SHORT Plo(9)         ! PLOTTER LOW LIMITS
980    SHORT Dout(1000,9)   ! DATA OUTPUT ARRAY (GETS REDIMENSIONED LATER)
990    !
1000   DIM B3(3),B2(3)      ! BASELINE FREQUENCIES FOR F2(EF) AND F3(CC)
1010   DIM T(3,3)           ! COEFFICIENTS OF C, D & E IN B(n-1), B(n), B(n+1)
1020   DIM Tinv(3,3)        ! INVERSE OF T ABOVE TO SOLVE FOR C, D & E.
1030   DIM C2(3),C3(3)      ! C2(1)=C, C2(2)=D, C2(3)=E FOR F2(EF); C3(*) FOR F3.
1040   DIM Tei(3),Teq(3)    ! COEFFICIENTS OF C, D & E IN I(n) AND Q(n)
1050   !
1060   Nvar=10              ! NUMBER OF INPUT VARIABLES
1070   Mav=50               ! MAXIMUM AVERAGING SPAN (NAV). MUST AGREE WITH DIM
1080                        ! OF DBUF,WT.
1090   Msout=1000           ! MAXIMUM SCANS OUT.  MUST AGREE WITH DIM OF DOUT.
```

```
1100  Nvout=9               ! MAXIMUM VARIABLES OUT. MUST AGREE WITH DIM OF DOUT,
1110                        ! PHI,PLO,VAR$
1120  Bad=0                 ! FLAG USED FOR BAD DATA OUT
1130  !
1140  ! SETUP FOR MULTIPLE INPUT FILE PROCESSING.
1150  !
1160  DIM Ifile$(100)       ! INPUT FILE NAMES
1170  DIM Ofile$(100)       ! OUTPUT FILE NAMES
1180  DIM Nav(100)          ! NUMBER OF SCANS TO AVERAGE
1190  DIM Nstep(100)        ! NUMBER OF SCANS TO STEP THE AVERAGES BY; USUALLY
1200                        ! AVERAGES ARE OVERLAPPED 50% OR SO
1210  DIM String$(100)[80]! CALIBRATION CONSTANTS FROM THE XCAL FILE FOR EACH
1220                         ! FILE
1230  DIM Comment$(100)[160] ! COMMENTS FROM EACH INPUT FILE.
1240  !
1250  FOR File=1 TO 100
1260    DISP "INPUT FILE NO. ";File;"? (CLEAR TO TERMINATE)";
1270    EDIT " ",Ifile$(File)
1280    Ifile$=Ifile$(File)
1290    IF LEN(Ifile$)=0 THEN 2070
1300  !
1310    ASSIGN #1 TO Ifile$,Ret
1320    IF Ret=0 THEN 1350
1330    DISP "FILE NOT ON PRESENT DISC.  ";
1340    GOTO 1260
1350  !
1360    READ #1;Comment$(File)
1370  !
1380    EDIT "EDIT COMMENTS",Comment$(File)
1390  !
1400    INPUT "NUMBER OF SCANS IN EACH AVERAGING WINDOW ?",Nav(File)
1410    Nav=Nav(File)
1420    IF Nav>Mav THEN 1400 ! RESTRICT NAV TO MAV
1430  !
1440    INPUT "STEPPING INCREMENT?",Nstep(File)
1450    Nstep=Nstep(File)
1460  !
1470    IF LEN(Pfile$)=0 THEN Pfile$="XCAL  :T15"
1480    EDIT "EDIT calibration file name. (BLANK TO ENTER CAL BY HAND)",Pfile$
1490    IF LEN(Pfile$)=0 THEN 1720
1500  !
1510    INPUT "XTVP SERIAL NO. ? (ZERO TO SEARCH BY DROP NO.)",Serial
1520  !
1530    IF Serial=0 THEN INPUT "Drop ID.?",Dropid$
1540  !
1550    ASSIGN #3 TO Pfile$,Ret    ! ASSIGN UNIT NUMBER TO PARAMETER FILE NAME
1560    IF Ret<>0 THEN 1480        ! Ret SHOULD BE 0 IF FILE IS THERE
1570    READ #3,1                  ! REWIND FILE
1580    ON END #3 GOTO 1890        ! SET UP END OF FILE TRAP
1590    DISP "READING ";Pfile$
1600  !
1610  ! READ EACH STRING IN THE PARAMETER FILE SEARCHING FOR THE DROP ID
1620  ! OR SERIAL NUMBER.
1630  !
1640    READ #3;String$
1650    IF LEN(String$)<58 THEN String$=String$&RPT$(" ",58-LEN(String$))
```

```
1660    IF (Serial<>0) AND (VAL(String$[8,12])=Serial) THEN 1720
1670    IF (Serial=0) AND (TRIM$(String$[44,48])=TRIM$(Dropid$)) THEN 1720
1680    GOTO 1640
1690  !
1700  ! EDIT/ENTER THE CALIBRATION STRING.  THERE MUST BE A VALUE IN EACH FIELD
1710  !
1720    EDIT "EDIT:  Probe  Mod  Gcc Gcor   Gef Evco Cvco Drop   Fh   Fz",St
ring$
1730    GOTO 1830
1740  !
1750    IF ERRN=159 THEN 1870
1760    DISP ERRM$
1770    PAUSE
1780    GOTO 1860
1790  !
1800  ! DECODE THE CALIBRATION STRING WITH ERROR CHECKING AND TRAPPING
1810  ! TO CHECK THAT IT WILL DECODE WHILE PROCESSING WITHOUT HALTING.
1820  !
1830    ON ERROR GOTO 1750
1840    ENTER String$ USING 1850;Probe,Mod,Gcc,Gcor,Gef,Efvf,Ccvf,Drop$,Fh,Fz
1850    IMAGE #,7X,4(5N),6N,2(5N),5A,2(5N)
1860    OFF ERROR
1870    GOTO 1940
1880  !
1890    BEEP
1900    DISP "CANNOT FIND THE CALIBRATION STRING.  "
1910    WAIT 3000
1920    GOTO 1230
1930  !
1940    ASSIGN #3 TO *    ! UNASSIGN UNIT 3; PFILE$ IS NOT ASSIGNED.
1950    String$(File)=String$
1960  !
1970    EDIT "OUTPUT FILE NAME?",Ofile$(File)
1980    Ofile$=Ofile$(File)
1990  !
2000    IF LEN(Ofile$)=0 THEN 1940
2010    ASSIGN #2 TO Ofile$,Ret  ! CHECK TO SEE IF OUTPUT FILE ALREADY EXISTS;
2020    IF Ret=1 THEN 2050       ! FORCE USER TO USE ANOTHER NAME IF IT DOES.
2030    DISP "ALREADY EXSISTS -- CHOOSE ANOTHER NAME";
2040    GOTO 1970
2050  !
2060  NEXT File      ! END OF PARAMETER INPUT ******************************
2070  !
2080  Nfile=File-1  ! NUMBER OF INPUT FILES TO PROCESS
2090  !
2100  ! CANNOT USE THE 9872A PLOTTER WITH MULTIPLE FILE PROCESSING BECAUSE
2110  ! THERE IS NO AUTOMATIC PAPER FEED.
2120  !
2130  IF Nfile>1 THEN INPUT "PLOTTER ? (0=NONE, 1=GRAPHICS, 3=9872S)",Plotter
2140  IF Nfile=1 THEN INPUT "PLOTTER ? (0=NONE, 1=GRAPHICS, 2=9872A, 3=9872S)",P
lotter
2150  IF (Plotter<0) OR (Plotter>3) THEN 2130
2160  IF (Nfile>1) AND (Plotter=2) THEN 2130
2170  !
2180  ! ACTUAL PROCESSING STARTS HERE AND REQUIRES NO MORE OPERATOR RESPONSES.
2190  !
```

```
2200 FOR File=1 TO Nfile
2210   String$=String$(File)
2220   ! CALIBRATION CONSTANTS DECODED FOR USE
2230   ENTER String$ USING 1850;Probe,Mod,Gcc,Gcor,Gef,Efvf,Ccvf,Drop$,Fh,Fz
2240   !
2250   Ifile$=Ifile$(File)
2260   Ofile$=Ofile$(File)
2270   Nav=Nav(File)
2280   Nstep=Nstep(File)
2290   !
2300   ASSIGN #1 TO Ifile$   ! ASSUMES IFILE$ IS PRESENT BECAUSE CHECKED BEFORE
2310   READ #1,1
2320   READ #1;Comment$      ! INPUT DATA IS ONE COMMENT$ STRING FOLLOWED BY
2330                         ! DIGITAL RECEIVER DATA NUMERIC VALUES.
2340   REDIM Dout(Msout,9)   ! SET DOUT TO MAX SIZE AFTER PREVIOUS FILES USE
2350   !
2360   ON Mod-3 GOTO 2430,2480,2530
2370   ! PROBE PHASE FROM CIRCUIT ANALYSIS DEPENDS ON MODEL NUMBER.
2380   ! ART BARTLETT AT W.H.O.I. MADE MOD 4.
2390   ! SIPPICAN MANUFACTURED MOD 5 ONLY FOR TOM SANFORD AT W.H.O.I. IN
2400   ! MAY 1979.
2410   ! SIPPICAN MANUFACTURED MOD 6 AFTER JULY 1979.
2420 !
2430   Gefp=15.2         ! XTVP MOD 4 (WHOI/BARTLETT-MADE)
2440   Gcorp=-165.1
2450   Gccp=-179.0
2460   GOTO 2680
2470 !
2480   Gefp=10.9         ! XTVP MOD 5 (SIPPICAN-MADE FOR AUTEC WORK ONLY)
2490   Gcorp=-169.3
2500   Gccp=-177.7
2510   GOTO 2680
2520 !
2530   Gefp=15.2         ! XTVP MOD 6 (SIPPICAN-MADE AFTER JULY 1979)
2540   Gcorp=-165.1
2550   Gccp=-179.0
2560   !
2570   Gefp0=45.77142872  ! QUADRATIC FITS VS ROTATION FREQUENCY
2580   Gefp1=-6.29750005  ! DETERMINED ANALYTICALLY FOR MOD 6 PROBES
2590   Gefp2=.276785719
2600   !
2610   Gcorp0=-133.4857151
2620   Gcorp1=-6.5403571
2630   Gcorp2=.29107141
2640   !
2650   Gccp0=-176.0285726
2660   Gccp1=-.5978569
2670   Gccp2=.02499997
2680 !                   ! CONVERT TO NEW LINGO
2690   Gcora=Gcor
2700   Gcca=Gcc
2710   Gefa=Gef
2720   Gevfa=Efvf
2730   Gcvfa=Ccvf
2740   Gevfp=0
2750   Gcvfp=0
```

```
2760  !
2770    Esep=5.12    !cm     ! PROBE PHYSICAL PARAMETERS
2780    C1=.97
2790    C2=-.02
2800  !
2810    DATA .00129299,.00023488,.980557E-7    ! CAL FOR SIPPICAN THERMISTOR
2820    RESTORE 2810
2830    READ Tecala,Tecalb,Tecalc               ! PUT ABOVE DATA IN TECALA,B,C
2840  !
2850    DATA -11336.3,7302.0  ! TEMP RESISTANCE VS MS
2860    RESTORE 2850
2870    READ Teres0,Teres1    ! PUT ABOVE DATA IN TERES0,1
2880  !
2890    DATA 3.1,4.544,-.0006749 ! PRESSURE VS TIME CAL
2900    RESTORE 2890
2910    READ Pcal0,Pcal1,Pcal2   ! PUT ABOVE DATA IN PCAL0,1,2
2920  !
2930  ! RCVR SCALE FACTORS FOR EACH FREQUENCY CHANNEL:
2940  !
2950    S1=1/200              ! S1,S2,S3 ARE INVERSE OF PHASE LOCK LOOP
2960    S2=1/40               ! MULTIPLICATION FACTORS.
2970    S3=1/20
2980    !
2990    Sff2=2*PI/4*S2        ! SFF2,3 ARE SCALE FACTORS TO CONVERT I & Q
3000    Sff3=2*PI/4*S3        ! TO THE AMPLITUDE OF THE FREQUENCY DEVIATIONS.
3010    !
3020    Sffe=Sff2                ! FOR MOD 5 PROBES F3 WAS EF AND F2 WAS CC
3030    IF Mod=5 THEN Sffe=Sff3  ! FOR ALL OTHERS F3=CC ANC F2=EF
3040  !
3050    Sfv=100/Fz/Esep/(1+C1)   ! SCALE FACTOR OF VELOCITY FROM EF
3060    Sfw=Fh/Fz*(1+C2)/(1+C1)  ! SCALE FACTOR OF Uw FROM W
3070    Sfa=100/2/PI/Fh          ! SCALE FACTOR FOR AREA FROM VC0/FREQ
3080  !
3090    REDIM Wt(Nav)            ! BARTLETT WINDOW FOR FILTERING
3100    FOR I=1 TO (Nav+1) DIV 2 ! (TRIANGULAR WINDOW, SUM NORMALIZED TO 1.0)
3110    Wt(I)=Wt(Nav+1-I)=I
3120    NEXT I
3130    MAT Wt=Wt/(SUM(Wt))
3140  !
3150    Sync=30583                  ! SYNC WORD EXPECTED FROM DIGITAL RECEIVER
3160  !
3170    Mastertime$=Comment$[1,18] ! REAL-TIME WHEN DXGET WAS RUN
3180  !
3190    Oscan=Iscan=Nhave=Falling=Time=Mastertime=Launchtime=0
3200  !
3210    Nwant=Nav+2      ! WANT THE INPUT BUFFER TO OVERLAP A VALUE ON EACH END
3220  !
3230    MAT Dout=(Bad)   ! INITIALIZE THE OUTPUT DATA ARRAY
3240  !
3250    DISP "LOOKING FOR PF ON"
3260  !
3270 Mainloop:  !                        MAINLOOP
3280    Npush=Nstep
3290    Coll$=""
3300  !
3310 Pushdown:  !                        PUSHDOWN DBUF(*) BY NSTEP SCANS
```

```
3320    REDIM Dbuf(1:Nwant,2:Nvar)
3330    IF Npush<Nhave THEN 3360
3340      Nhave=0
3350      GOTO Getmore
3360    FOR I=Npush+1 TO Nhave
3370      J=I-Npush
3380      FOR L=2 TO Nvar
3390        Dbuf(J,L)=Dbuf(I,L)
3400      NEXT L
3410    NEXT I
3420    Nhave=Nhave-Npush
3430   !
3440 Getmore:  ! GETMORE KEEPING IN SYNC.
3450           ! EARLY VERSIONS OF THE DIGITAL RECEIVER WOULD GIVE DATA
3460           ! TOO FAST FOR DXGET AND THUS WOULD GET OUT OF SYNC
3470    READ #1;Din(*)     ! READ ONE INPUT SCAN AT A TIME UNLESS LOSE SYNC
3480                       ! THEN READ ONE VALUE AT A TIME UNTIL SNYC'D AGAIN
3490    IF (Din(2)<>Sync) AND (Din(11)=Sync) THEN 3590
3500    IF Iscan>0 THEN PRINT "LOST SYNC BEFORE ISCAN=";Iscan
3510    Din0=Din(2)
3520    FOR I=2 TO Nvar
3530      Din(I)=Din(I+1)
3540    NEXT I
3550    READ #1;Din(Nvar+1)
3560    IF Din0<>Sync THEN 3510
3570    GOTO 3490
3580   !
3590    Iscan=Iscan+1
3600    Mastertime=Mastertime+Din(4)*1E-5
3610   ! PRINT USING "11(7D)";Iscan,Din(*)   ! DEBUGGING PRINT
3620   !                                 TEST STATUS WORD
3630    Status=Din(2)
3640   ! THE NUMBER OF WORDS TAKEN IN THE LAST SCAN IS ENCODED IN BITS 11-8
3650    IF (SHIFT(Status,8)<>Nvar) AND (Iscan>1) THEN PRINT "MISSED SCAN(S) FROM
 DR AT ISCAN=";Iscan
3660   ! BITS 2-0 INDICATE IF THE CARRIERS ARE PRESENT LIKE THE LIGHTS ON PANEL.
3670   ! WHEN THE PROBE IS LAUNCHED THE CARRIERS SHOULD ALL COME ON
3680    IF Launchtime OR NOT BIT(Status,"111") THEN 3740
3690      Launchtime=Mastertime
3700      CALL Addtime(Mastertime$,Launchtime$,Launchtime)
3710      PRINT "LAUNCH-TIME=",Launchtime$,Launchtime,"ISCAN=";Iscan
3720   ! BIT 3 OF STATUS SHOWS THE PF LIGHT ON PANEL.  IT IS ON WHEN THE CC
3730   ! CHANNEL DEVIATES MORE THAN A PRE-SET THRESHHOLD.
3740    IF NOT Falling AND (BIT(Status,3)=0) THEN Getmore
3750   !                                 TRANSFER FROM DIN TO DUF
3760    Nhave=Nhave+1
3770    FOR L=2 TO Nvar
3780      Dbuf(Nhave,L)=Din(L)
3790    NEXT L
3800    IF Nhave<Nwant THEN Getmore
3810   !
3820    REDIM Dbuf(0:Nwant-1,2:Nvar)
3830   !   USE PROBE FALLING (PF) BIT TO START AND STOP PROCESSING:
3840    Npf=0              ! WANT NPF=NAV TO START PROCESSING
3850    FOR I=1 TO Nav     ! ALLOW NPF<NAV TO STOP PROCESSING WHEN TIME>200 SEC
3860      Npf=Npf+BIT(Dbuf(I,2),3)
```

```
3870    NEXT I
3880    IF Falling OR (Npf=Nav) THEN 3910
3890      Npush=1
3900      GOTO Pushdown
3910    IF (Time>200) AND (Npf<Nav) THEN Endloop
3920    IF Npf=0 THEN Endloop
3930    IF Falling THEN 4000
3940      Falling=1
3950      Downtime=Mastertime
3960      CALL Addtime(Mastertime$,Downtime$,Downtime)
3970      PRINT "DOWN-TIME=",Downtime$,Downtime,"ISCAN=";Iscan-Nwant+1
3980      DISP "PROCESSING FILE ";File;". IFILE=";Ifile$;", OFILE=";Ofile$
3990    !
4000    ! COMPUTE THE ERROR TERMS IN I AND Q THEN CORRECT DBUF FOR NEW SCANS
4010    ! (THE OLD SCANS WERE CORRECTED ALREADY BECAUSE DBUF WAS PUSHED DOWN)
4020    !
4030    J1=Nhave-Npush-1
4040    IF Oscan>0 THEN 4160
4050      J1=1
4060      ! T1 = T(n-1) in report
4070      ! T2 = T(n)
4080      ! T3 = T(n+1)
4090      T11=Dbuf(J1-1,4)*1E-5  ! T11 IS T1
4100      T12=T11*T11            ! T12 IS T1 SQUARED
4110      T13=T12*T11            ! T13 IS T1 CUBED
4120      T21=Dbuf(J1,4)*1E-5
4130      T22=T21*T21
4140      T23=T22*T21
4150      D3=1/3
4160    J2=Nav
4170      FOR J=J1 TO J2
4180        I=J-1
4190        K=J+1
4200        T31=Dbuf(K,4)*1E-5
4210        T32=T31*T31
4220        T33=T32*T31
4230        T(1,1)=T11           ! SET UP T(*) TO SOLVE FOR C,D,E GIVEN B1,B2,B3.
4240        T(1,2)=-.5*T12       ! C,D,E ARE COMPUTED IN C2(*) AND C3(*) FOR
4250        T(1,3)=D3*T13        ! EF AND CC RESPECTIVELY.
4260        T(2,1)=T21
4270        T(2,2)=.5*T22
4280        T(2,3)=D3*T23
4290        T(3,1)=T31
4300        T(3,2)=T21*T31+.5*T32
4310        T(3,3)=T22*T31+T21*T32+D3*T33
4320        MAT Tinv=INV(T)
4330        B3(1)=Dbuf(I,7)
4340        B2(1)=Dbuf(I,8)
4350        B3(2)=Dbuf(J,7)
4360        B2(2)=Dbuf(J,8)
4370        B3(3)=Dbuf(K,7)
4380        B2(3)=Dbuf(K,8)
4390        MAT C3=Tinv*B3         ! C3(*)=C,D,E FOR COIL CHANNEL
4400        MAT C2=Tinv*B2         ! C2(*)=C,D,E FOR EF CHANNEL
4410        Tei(1)=T11-T21
4420        Tei(2)=.25*T12-.5*T22
```

```
4430        Tei(3)=T13/12-T23/3
4440        Teq(1)=1.25*(T11-T21)
4450        Teq(2)=(17*T12-25*T22)/32
4460        Teq(3)=(53*T13-125*T23)/192
4470        Ei3=DOT(Tei,C3)       ! COMPUTE I AND Q ERRORS FOR EF AND CC
4480        Ei2=DOT(Tei,C2)
4490        Eq3=DOT(Teq,C3)
4500        Eq2=DOT(Teq,C2)
4510        ! debugging printout
4520        IF NOT Debugging THEN 4580
4530          IF J=J1 THEN PRINT LIN(1);" ISCAN STATUS   TEMP PERIOD    Icc     I
ef   BLcc   BLef    Qcc    Qef"
4540          PRINT USING 4550;Iscan-Nwant+J,Dbuf(J,2),Dbuf(J,3),Dbuf(J,4),Dbuf(
J,5),Dbuf(J,6),Dbuf(J,7),Dbuf(J,8),Dbuf(J,9),Dbuf(J,10)
4550          IMAGE 6D,9(7D)
4560          PRINT USING 4570;Ei3,Ei2,Eq3,Eq2
4570          IMAGE 14X,"I & Q ERRORS:",7D,7D,14X,7D,7D
4580        Dbuf(J,5)=Dbuf(J,5)-Ei3  ! SUBTRACT ERRORS FROM DBUF
4590        Dbuf(J,6)=Dbuf(J,6)-Ei2
4600        Dbuf(J,9)=Dbuf(J,9)-Eq3
4610        Dbuf(J,10)=Dbuf(J,10)-Eq2
4620        IF NOT Debugging THEN 4650
4630          PRINT USING 4640;Dbuf(J,5),Dbuf(J,6),Dbuf(J,9),Dbuf(J,10)
4640          IMAGE 13X,"I & Q RESULTS:",7D,7D,14X,7D,7D
4650        T11=T21    ! PUSH DOWN SOME STUFF TO SPEED PROCESSING
4660        T12=T22    ! INSTEAD OF RECOMPUTING
4670        T13=T23
4680        T21=T31
4690        T22=T32
4700        T23=T33
4710      NEXT J
4720    !
4730    ! NORMALIZE THE DBUF DATA TO GET THE FREQUENCY AMPLITUDES OF THE PROBE.
4740    ! APPLY THE BARTLETT FILTERING WINDOW TO DBUF(*).
4750    !
4760    MAT Dav=ZER
4770    Eis=Eiss=Eqs=Eqss=0
4780    !
4790    FOR J=1 TO Nav
4800      Wt=Wt(J)
4810      T1=Dbuf(J-1,4)*1E-5
4820      T2=Dbuf(J,4)*1E-5
4830      Dt=Dbuf(J,4)-Dbuf(J-1,4)
4840      Rfi=1/T2
4850      Rfq=1/(1.25*T2-.25*T1)
4860      Wtri=Wt*Rfi
4870      Wtrq=Wt*Rfq
4880      Dav(3)=Dav(3)+Dbuf(J,3)*Wtri
4890      Dav(4)=Dav(4)+Dbuf(J,4)*Wt
4900      Dav(7)=Dav(7)+Dbuf(J,7)*Wtri
4910      Dav(8)=Dav(8)+Dbuf(J,8)*Wtri
4920      Dav(5)=Dav(5)+Dbuf(J,5)*Wtri
4930      Dav(6)=Dav(6)+Dbuf(J,6)*Wtri
4940      Dav(9)=Dav(9)+Dbuf(J,9)*Wtrq
4950      Dav(10)=Dav(10)+Dbuf(J,10)*Wtrq
4960     !                            SUMS AND SUMS OF SQUARES TO COMPUTE RMS ERR
```

```
4970      IF Mod=5 THEN 5050
4980      Ei=Dbuf(J,6)*Rfi
4990      Eq=Dbuf(J,10)*Rfq
5000      Eis=Eis+Ei
5010      Eiss=Eiss+Ei^2
5020      Eqs=Eqs+Eq
5030      Eqss=Eqss+Eq^2
5040      GOTO 5110
5050      Ei=Dbuf(J,5)*Rfi
5060      Eq=Dbuf(J,9)*Rfq
5070      Eis=Eis+Ei
5080      Eiss=Eiss+Ei^2
5090      Eqs=Eqs+Eq
5100      Eqss=Eqss+Eq^2
5110    !
5120    NEXT J
5130  !                               ROTATION FREQ AND PERIOD
5140    Rotp=Dav(4)*1E-5
5150    Rotf=1/Rotp
5160  ! TIME IS COMPUTED BY SUMMING ALL THE PERIODS SINCE THE PROBE STARTED DOWN
5170    IF Oscan=0 THEN Time=Rotp*(Nav/2-Nstep)
5180    Time=Time+Nstep*Rotp
5190  !                             PROBE CARRIER FREQUENCIES
5200    F1b=Dav(3)*S1
5210    F2i=Dav(6)*Sff2
5220    F2q=Dav(10)*Sff2
5230    F2b=Dav(8)*S2
5240    F3i=Dav(5)*Sff3
5250    F3q=Dav(9)*Sff3
5260    F3b=Dav(7)*S3
5270  !                           PUT CARRIER FREQ'S IN PROPER VARIABLES
5280    IF Mod=5 THEN 5360
5290    Fcci=F3i
5300    Fccq=F3q
5310    Fccb=F3b
5320    Fefi=F2i
5330    Fefq=F2q
5340    Fefb=F2b
5350    GOTO 5420
5360    Fcci=F2i
5370    Fccq=F2q
5380    Fccb=F2b
5390    Fefi=F3i
5400    Fefq=F3q
5410    Fefb=F3b
5420  !                                         TEMPERATURE
5430    Tems=1000/F1b          ! PERIOD IN MILLISECONDS OF TEMPERATURE CARRIER
5440    Teres=Teres0+Teres1*Tems  ! THERMISTOR RESISTANCE
5450    IF Teres>0 THEN 5480
5460      Temp=Bad
5470      GOTO 5560
5480    Ln=LOG(Teres)
5490    Temp=1/(Tecala+Tecalb*Ln+Tecalc*Ln^3)-273.15  ! DEGREES C
5500  !          PROBE PHASES VS ROTATION FREQ USING QUADRATIC ESTIMATES
5510    R1=Rotf
5520    R2=Rotf^2
```

```
5530    Gefp=Gefp0+Gefp1*R1+Gefp2*R2
5540    Gcorp=Gcorp0+Gcorp1*R1+Gcorp2*R2
5550    Gccp=Gccp0+Gccp1*R1+Gccp2*R2
5560  !                                          COIL MICROVOLTS
5570    CALL Polar(-Fccq,-Fcci,Fcca,Fccp)
5580    Vc0a=Fcca/Gcvfa/Gcca*1E6    ! Eca in report
5590    Vc0p=Fccp-Gcvfp-Gccp        ! Ecp in report
5600  !                                          ELECTRODE MICROVOLTS
5610    CALL Polar(-Fefq,-Fefi,Fefa,Fefp)
5620    Ve0a1=Fefa/Gevfa/Gefa*1E6
5630    Ve0p1=Fefp-Gevfp-Gefp
5640    CALL Rect(Ve0a1,Ve0p1,Ve0q1,Ve0i1)
5650    Ve0a2=Fcca/Gcvfa/Gcca*Gcora/Gefa*1E6
5660    Ve0p2=Fccp-Gcvfp-Gccp+Gcorp-Gefp
5670    CALL Rect(Ve0a2,Ve0p2,Ve0q2,Ve0i2)
5680    Ve0q=Ve0q1-Ve0q2
5690    Ve0i=Ve0i1-Ve0i2
5700    CALL Polar(Ve0q,Ve0i,Ve0a,Ve0p)  ! Ve0a is Eea in report
5710                                     ! Ve0p is Eep in report
5720  !                                          FALL RATE, PRESSURE, Z=-PRESSURE
5730    W=-100*(Pcal1+2*Pcal2*Time)  ! emperically determined pressure vs time
5740    P=Pcal0+Time*(Pcal1+Time*Pcal2)
5750    Z=-P
5760  !                                          AREA OF COIL TIMES TURNS (cm^2)
5770    Area=Vc0a/Rotf*Sfa
5780  !              PHASE OF ZERO CROSSING DETECTOR circuit
5790    Zcdp=-90-Fccp
5800  !                                          VELOCITY COMPENSATION
5810    Uw=W*Sfw                                ! LIKE EMVP REPORT
5820    Betae=-Ve0p    ! Ve0p and Vc0p phases have signs so if the signal leads
5830    Betac=-Vc0p    ! the phases are positive.  Betae and Betac are opposite.
5840    Alpha=180      ! angle from electrode to coil
5850    Psi=Betae-Betac+90+Alpha  ! see EMVP report
5860    U=Ve0a*Sfv*COS(Psi)
5870    V=-Ve0a*Sfv*SIN(Psi)+Uw
5880  !
5890    Sfef=1E6/Gefa/Gevfa
5900    Rmserr=SQR(.5*(Eiss/Nav-(Eis/Nav)^2+Eqss/Nav-(Eqs/Nav)^2))*ABS(Sffe*Sfef
*Sfv)
5910    Velerr=Rmserr/SQR(Nav) ! normalize rmserr
5920  !                                          PRINT
5930    IF Debugging OR (Oscan MOD 20=0) THEN PRINT USING 5940
5940    IMAGE "   Z  Temp     U     V    W Rotf Area   Uw Vc0a Zcdp  Ve0a  Ve0p
Fefb Fccb Ver"
5950    PRINT USING 5960;Z,Temp,U,V,W,Rotf,Area,Uw,Vc0a,Zcdp,Ve0a,Ve0p,Feft,Fccb
,Velerr
5960    IMAGE  4D,3D.2D,2 (4D.D),5D,2D.2D,3(5D),3D.D,3D.2D,4D.D,2(5D),2D.D
5970  !
5980    Oscan=Oscan+1
5990    Dout(Oscan,1)=Z             ! STORE IN OUTPUT ARRAYS
6000    Dout(Oscan,2)=Temp
6010    Dout(Oscan,3)=U
6020    Dout(Oscan,4)=V
6030    Dout(Oscan,5)=Area
6040    Dout(Oscan,6)=Rotf
6050    Dout(Oscan,7)=Fefb
```

```
6060     Dout(Oscan,8)=Fccb
6070     Dout(Oscan,9)=Velerr
6080   !
6090     IF Oscan<Msout THEN Mainloop
6100   !
6110 Endloop: !
6120   !
6130     Nsout=Oscan-3
6140     REDIM Dout(Nsout,Nvout)
6150   !
6160   ! CORRECT FOR NORTH-SOUTH TILTS A LA D'ASARO
6170     Velerrmax=4
6180     Na=0
6190     Amean=0
6200     FOR Oscan=1 TO Nsout
6210       Velerr=Dout(Oscan,9)
6220       IF Velerr>Velerrmax THEN 6260
6230         Area=Dout(Oscan,5)
6240         Amean=Amean+Area
6250         Na=Na+1
6260     NEXT Oscan
6270   !
6280     Amean=Amean/Na
6290     PRINT USING "K,5D,K";"MEAN AREA=",Amean," cm^2"
6300   !
6310     FOR Oscan=1 TO Nsout
6320       Rotf=Dout(Oscan,6)
6330       Rotp=1/Rotf
6340       IF Oscan=1 THEN Time=Rotp*(Nav/2-Nstep)
6350       Time=Time+Nstep*Rotp
6360       W=-100*(Pcal1+2*Pcal2*Time)
6370       Area=Dout(Oscan,5)
6380       Vcor=W*Sfw*(Area/Amean-1)
6390       V=Dout(Oscan,4)
6400       V=V+Vcor
6410       Dout(Oscan,4)=V
6420     ! PRINT USING "K,DDD.D,K,DDD.D";"VCOR=",Vcor,"V=";V
6430     NEXT Oscan
6440   !
6450     DATA "Z","T","U","V","AREA","FREQ","EF BL","CC BL","VELERR"
6460     RESTORE 6450
6470     READ Var$(*)
6480   !
6490     IF LEN(Ofile$)=0 THEN 6680
6500     ! compute number of records to create file to hold data.
6510     L=LEN(Drop$)+8+LEN(Downtime$)+8+LEN(Lat$)+8+LEN(Long$)+8
6520     L=L+LEN(Comment$)+8+LEN(Progrev$)+8+LEN(Ifile$)+8+LEN(Runtime$)+8
6530     L=L+8*4+8*11
6540     FOR I=1 TO ROW(Var$)
6550       L=L+LEN(Var$(I))+8
6560     NEXT I
6570     L=L+4*ROW(Dout)*COL(Dout)
6580     Nrec=L/256 DIV 1+1
6590     !
6600     CREATE Ofile$,Nrec    ! standard xtvp data format
6610     ASSIGN Ofile$ TO #2
6620     PRINT #2;Drop$,Downtime$,Lat$,Long$,Comment$,Progrev$,Ifile$,Runtime$
```

```
6630   PRINT #2;Nvout,Nsout,Bad,11
6640   PRINT #2;Nav,Nstep,Probe,Mod,Gcc,Gcor,Gef,Efvf,Ccvf,Fh,Fz
6650   PRINT #2;Var$(*),Dout(*)
6660   PRINT #2;END
6670   ASSIGN #2 TO *
6680 !
6690   DATA -1000,   0,-30,-30, 600,  6,2000,4000, 0  ! plotting scales
6700   DATA     0,  28, 40, 40,1300,9.5,3000,5000,70
6710   DATA -1000,   0,-30,-30, 700,  6,4000,2000, 0
6720   DATA     0,  28, 40, 40,1400,9.5,5000,3000,70
6730   IF Mod<>5 THEN RESTORE 6690
6740   IF Mod=5 THEN RESTORE 6710
6750   READ Plo(*),Phi(*)
6760 !
6770 !                                      SETUP PLOTTER FOR 7 WIDE  BY 10 HIGH
6780   ON Plotter+1 GOTO 8340,6790,6840,6890
6790 !
6800   PLOTTER IS "GRAPHICS"
6810   LIMIT 0,7*25.4,0,5*25.4
6820   GRAPHICS
6830   GOTO 6930
6840 !                                       SETUP 9872A
6850   IF File=1 THEN PLOTTER IS "9872A"
6860   LIMIT 600/40,7730/40,280/40,10440/40
6870   FRAME
6880   GOTO 6930
6890 !                                       SETUP 9872S
6900   IF File=1 THEN PLOTTER IS "9872A"
6910   LIMIT 600/40,7730/40,1060/40,11220/40
6920   FRAME
6930 !
6940 Nhalf=1
6950 IF Plotter=1 THEN Nhalf=2
6960 FOR Half=1 TO Nhalf
6970 IF (Plotter=1) AND (Half=1) THEN 7310
6980   LINE TYPE 1
6990   PEN 1
7000   SETGU
7010   Xgdumax=100*MAX(1,RATIO)
7020   MOVE Xgdumax-25,60
7030   IF Plotter=1 THEN MOVE Xgdumax-45,97
7040   CSIZE 3
7050   IF Plotter=1 THEN CSIZE 3.89
7060   LABEL USING "K";"PROG=";Progrev$
7070   LABEL USING "K";"IFILE=";Ifile$
7080   LABEL USING "K";"OFILE=";Ofile$
7090 !
7100   CSIZE 2
7110   IF Plotter=1 THEN CSIZE 3.89
7120   LABEL USING "K";Runtime$
7130   LABEL USING "K";"NAV=";Nav
7140   LABEL USING "K";"NSTEP=";Nstep
7150   LABEL USING "K";"XTVP S/N=";Probe
7160   LABEL USING "K";"XTVP MOD=";Mod
7170   LABEL USING "K";"GCC=";Gcc
7180   LABEL USING "K";"GCOR=";Gcor
7190   LABEL USING "K";"GEF=";Gef
```

```
7200   LABEL USING "K";"EVCO=";Efvf
7210   LABEL USING "K";"CVCO=";Ccvf
7220   LABEL USING "K";"FH=";Fh
7230   LABEL USING "K";"FZ=";Fz
7240  !                                        PLOT EACH VARIABLE
7250   Csize=2
7260   IF Plotter=1 THEN Csize=3.89
7270   CSIZE Csize
7280  !
7290   LABEL USING "5A,2(5D.D)";Var$(1),Plo(1),Phi(1)
7300   WHERE Xlab,Ylab
7310  !
7320   FOR Var=2 TO Nvout
7330     Pen=MIN(Var-1,4)
7340     IF Var=9 THEN Pen=1
7350     IF NOT Pub THEN PEN Pen
7360     IF Pub THEN PEN 1
7370     !
7380     IF (Plotter=1) AND (Half=1) THEN 7440
7390     LINE TYPE 1
7400     SETGU
7410     MOVE Xlab,Ylab
7420     LABEL USING "5A,2(5D.D)";Var$(Var),Plo(Var),Phi(Var)
7430     WHERE Xlab,Ylab
7440     !
7450     LINE TYPE 1
7460  IF NOT Pub THEN 7570
7470  PEN 1
7480  IF Var=2 THEN LINE TYPE 4,4
7490  IF Var=3 THEN LINE TYPE 4,1
7500  IF Var=4 THEN LINE TYPE 4,2
7510  IF Var=5 THEN LINE TYPE 7,2
7520  IF Var=6 THEN LINE TYPE 5,2
7530  IF Var=7 THEN LINE TYPE 7,4
7540  IF Var=8 THEN LINE TYPE 8,4
7550  IF Var=9 THEN LINE TYPE 1
7560  GOTO 7610
7570     IF (Plotter=1) AND (Var=4) THEN LINE TYPE 3
7580     IF Var=6 THEN LINE TYPE 5,1
7590     IF Var=7 THEN LINE TYPE 5,2
7600     IF Var=8 THEN LINE TYPE 5,3
7610     !
7620     IF (Plotter=1) AND (Half=1) THEN 7660
7630     MOVE Xlab,Ylab+.8*Csize
7640     DRAW Xlab+11*Csize,Ylab+.8*Csize
7650     Ylab=Ylab-.2*Csize
7660     !
7670     SCALE Plo(Var),Phi(Var),Plo(1),Phi(1)
7680     IF (Plotter=1) AND (Half=1) THEN SCALE Plo(Var),Phi(Var),Plo(1)/2,Phi(
1)
7690     IF (Plotter=1) AND (Half=2) THEN SCALE Plo(Var),Phi(Var),Plo(1),Plo(1)
/2
7700    !                                        PLOT THE DATA
7710     P=-2
7720     FOR I=1 TO Nsout
7730       D=Dout(I,Var)
7740       IF D<>Bad THEN 7770
```

```
7750         P=-2
7760         GOTO 7810
7770       !
7780         Z=Dout(I,1)
7790         PLOT D,Z,P
7800         P=-1
7810       NEXT I
7820       SETGU
7830       MOVE 130,0
7840     NEXT Var
7850     IF Plotter<>1 THEN 8070
7860       PEN 1
7870       SCALE 0,1,0,1
7880       IF Half<>1 THEN 7930
7890       MOVE 0,0              ! PARTIAL FRAMES
7900       DRAW 0,1
7910       DRAW 1,1
7920       DRAW 1,0
7930       IF Half<>2 THEN 8030
7940       MOVE 0,1
7950       DRAW 0,0
7960       DRAW 1,0
7970       DRAW 1,1
7980       !
7990       SETGU
8000       MOVE 1,1
8010       PEN 1
8020       LABEL USING "K";Comment$
8030       !
8040       SCALE 0,1,0,1
8050       DUMP GRAPHICS 0,1
8060       GCLEAR
8070   NEXT Half
8080     !
8090     CSIZE Csize
8100     IF Plotter=1 THEN 8150
8110       SETGU
8120       MOVE 1,1
8130       PEN 1
8140       LABEL USING "K";Comment$
8150   !
8160     MOVE 100,0
8170     PEN 0
8180   !
8190     IF Plotter<>1 THEN 8240
8200       EXIT GRAPHICS
8210       PRINTER IS 0
8220       PRINT PAGE;         ! TOP OF FORM ON PRINTER
8230       PRINTER IS Printer
8240     IF Plotter<>3 THEN 8270
8250       OUTPUT 705;"EC"     ! enable cutter on 9872S
8260       OUTPUT 705;"AH"     ! advance half page on 9872S
8270     IF Nfile>1 THEN 8340
8280   ! ONLY EXECUTE THE FOLLOWING CODE IF NFILE=1
8290     FOR V=1 TO Nvout  ! allow different plot scales
8300       DISP Var$(V);Plo(V);Phi(V);
8310       INPUT "ENTER NEW PLOT LIMITS: PLO, PHI",Plo(V),Phi(V)
```

```
8320    NEXT V
8330    GOTO 6770
8340  NEXT File
8350  DISP "FINISHED"
8360  STOP
8370  !
8380  ! ********************************************************************
8390  DEF FNAtan2(Y,X)              ! FN ATAN2(Y,X) four quadrant arc-tangent
8400  DEG
8410  IF X=0 THEN Vert
8420  Ang=ATN(Y/X)
8430  IF X>0 THEN RETURN Ang
8440  IF Y<0 THEN Q3
8450  Ang=Ang+180
8460  RETURN Ang
8470 Q3:  Ang=Ang-180
8480  RETURN Ang
8490 Vert:  IF Y<0 THEN Down
8500  Ang=90
8510  RETURN Ang
8520 Down:  Ang=-90
8530  RETURN Ang
8540  FNEND
8550  ! ***********************************************************************
8560  SUB Interp(Nin,Nout,Bad,Dzout,SHORT Pin(*),Din(*),Dou(*))
8570  SUBEND
8580  ! **********************************************************************
8590  SUB Addtime(Mastertime$,Addtime$,Addsecs)
8600  ENTER Mastertime$ USING "#,4(NN,X),NN";Mo,Da,Hr,Mn,Sc
8610  Sc=Sc+Addsecs
8620  Mn=Mn+Sc DIV 60
8630  Sc=Sc MOD 60
8640  Hr=Hr+Mn DIV 60
8650  Mn=Mn MOD 60
8660  Da=Da+Hr DIV 24
8670  Hr=Hr MOD 24
8680  OUTPUT Addtime$ USING 8690;Mo,Da,Hr,Mn,Sc
8690  IMAGE #,4(ZZ,":"),ZZ
8700  SUBEND
8710  ! *****************************************************************
8720  SUB Polar(X,Y,Amp,Ang)    ! rectangular to polar conversion
8730  DEG
8740  Amp=SQR(X^2+Y^2)
8750  IF X<>0 THEN Ang=ATN(Y/X)
8760  IF (X<0) AND (Y<0) THEN Ang=Ang-180
8770  IF (X<0) AND (Y>=0) THEN Ang=Ang+180
8780  IF (X=0) AND (Y>0) THEN Ang=90
8790  IF (X=0) AND (Y<0) THEN Ang=-90
8800  SUBEND
8810  ! **************************************************************
8820  SUB Rect(Amp,Ang,X,Y)     ! polar to rectangular conversion
8830  DEG
8840  X=Amp*COS(Ang)
8850  Y=Amp*SIN(Ang)
8860  SUBEND
8870  ! **************************************************************
```

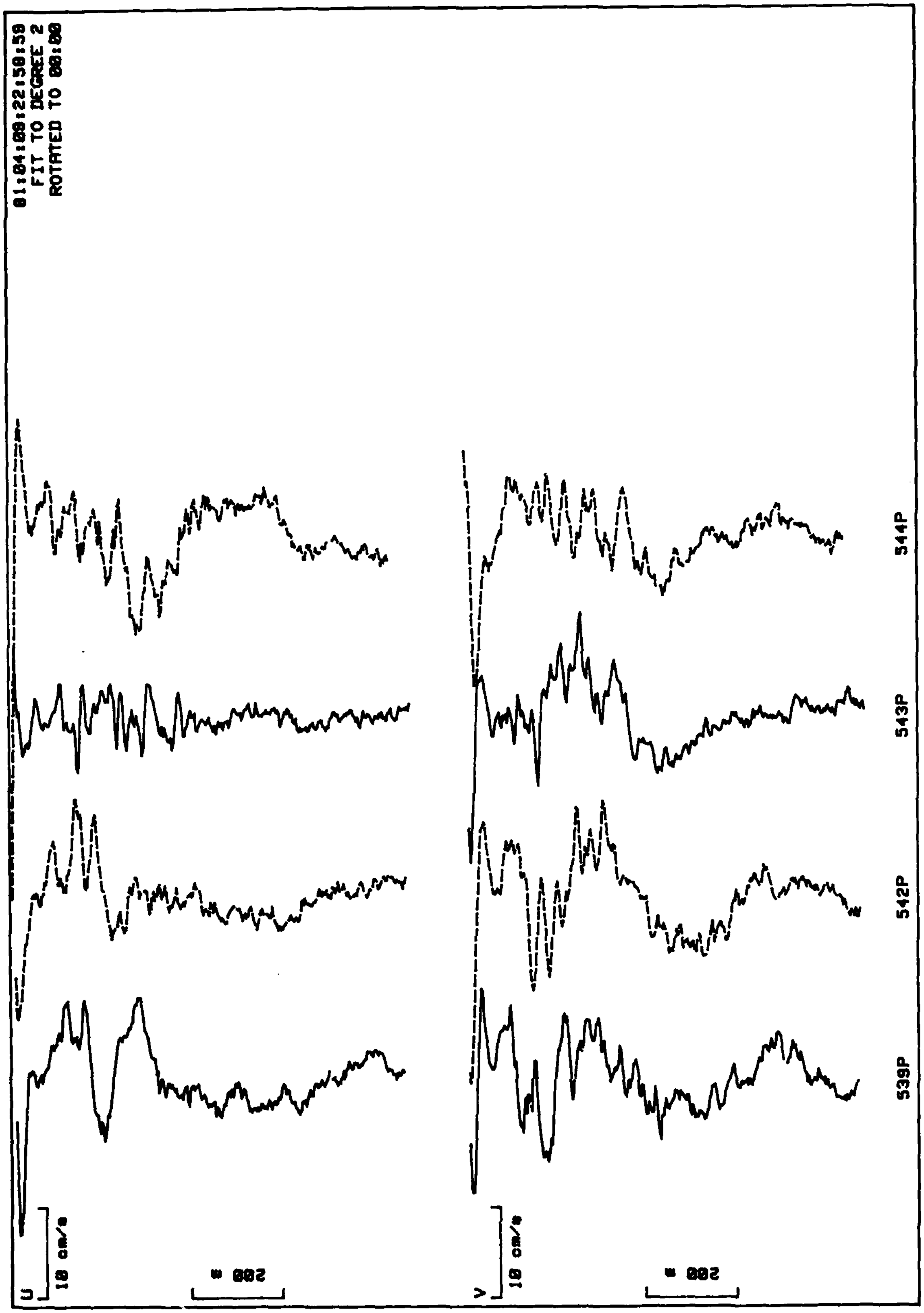
Program SPLOT, Sample Run

SPLOT produces a series of plots of XTVP profiles. Many features are available. One can fit each profile to a polynomial and rotate the profile based on its time and inertial period. One can plot the fit or the profile minus the fit.

The following example shows the program prompts, operator entries and program responses for a typical run of plotting, in Cartesian coordinates, the rotated residues of quadratic fits to each of four profiles.

```
SPLOTO               RUN DATE/TIME=81:04:09:22:55:56
VARIABLE NAMES USED ARE U,V
VELOCITY ERROR LIMIT= 2
DATA FITTED TO A POLYNOMIAL OF DEGREE  2
PLOT THE RESIDUE
PLOTS ARE CARTESIAN
THE RESIDUE PROFILES WERE ROTATED BASED ON REF.TIME OF  0 hr  0 min
  FOR A ROTATION PERIOD OF  13.4088046171
ROTATED TO 00:00
A PLOT OF THE RESIDUE WAS MADE USING PEN #1
PLOT IS LABELLED.
INPUT DATA IS PROCESSED.
TIC SIZE = 17.78  mm
PLOT WILL BE  266.7 mm 10.5 in WIDE AND  177.8  mm  7 in HIGH
FILE NO.  FILE NAME    TIME HR MIN      U,V OFFSETS (TICS)
   1      539P              00:32          4.0  4.0
   2      542P              01:29          4.0  4.0
   3      543P              01:56          4.0  4.0
   4      544P              02:23          4.0  4.0
TOP 0 m OF PROFILES ZAPPED
PLOT MADE 81:04:09:22:58:59
 1 FILE NAME=539P
  539                12:02:02:35:50
12:02:02:35:42 XTVP 539 PLAYBACK FAEROES PAT
CREATED BY DXPROW FROM FILE 539R, ON 80:12:04:17:39:41
AVERAGE FIT. NBLOCKS= 30 A= 31.1841502298 -.28223036716 4.97020250700E-04
AVERAGE FIT. NBLOCKS= 30 A= -9.659564307 -.06076936805 2.26920819670E-04
INPUT FILE,VARIABLE,NO. OF GOOD PTS,AVE.,STD. DEV. BASED ON GOOD PTS
    539P      U COMP        295    .143      3.921
    539P      V COMP        295    .072      3.788
 2 FILE NAME=542P
  542                12:02:18:42:02
12:02:18:41:56 XTVP 542 PLAYBACK FAEROES PAT
CREATED BY DXPROW FROM FILE 542R, ON 80:12:04:18:40:10
AVERAGE FIT. NBLOCKS= 30 A= 23.6964354786 -.22058932126 3.60916726720E-04
AVERAGE FIT. NBLOCKS= 30 A= -9.2035525367 -.05074011791 2.38360188330E-04
    542P      U COMP        279    .162      3.243
    542P      V COMP        279    .041      4.564
 3 FILE NAME=543P
  543                12:02:18:49:36
12:02:18:49:31 XTVP 543 PLAYBACK FAEROES PAT
CREATED BY DXPROW FROM FILE 543R, ON 80:12:04:18:40:10
AVERAGE FIT. NBLOCKS= 30 A= 21.7290090277 -.218441803637 4.43213723550E-04
AVERAGE FIT. NBLOCKS= 30 A= -14.0859444811 .06392939153 -1.48637570070E-04
```

```
    543P      U COMP        280    .035       1.613
    543P      V COMP        280    .142       3.508
 4 FILE NAME=544P
  544               12:02:19:00:11
12:02:19:00:06 XTVP 544 PLAYBACK FAEROES PAT
CREATED BY DXPROW FROM FILE 544R, ON 80:12:04:18:40:10
AVERAGE FIT. NBLOCKS= 30 A= 31.332172827 -.34130695143 7.04315634400E-04
AVERAGE FIT. NBLOCKS= 30 A= -20.1443709546 .1250602027 -3.00207033690E-04
    544P      U COMP        283   -.106       4.867
    544P      V COMP        283   -.037       3.698
```


01:04:08:22:50:59
FIT TO DEGREE 2
ROTATED TO 00:00
544P
543P
542P
539P
U
10 cm/s
200 m
V
10 cm/s
200 m

Program Listing of SPLOT

```
10      Progrev$="SPLOTO"
20      Year=81
30    ! SPLOT : SERIES PLOT BY TOM SANFORD MODIFICATIONS BY JOHN DUNLAP
40    !  THIS PROGRAM ALLOWS FILES TO BE REQUESTED WHICH ARE ON
50    ! SEPARATE DISKS AND PLOTTED WITH OFFSETS FOR Q(U) AND I(V).
60    ! SPLOTC ALLOWS POLYNOMIAL FIT AND RESIDUES TO BE PLOTTED.
70    ! SPLOTC ALLOWS THE PROFILES TO BE ROTATED CCW
80    ! SPLOTC ALLOWS THE RESIDUE PROFILES TO BE PLOTTED IN POLAR FORM
90    ! SPLOTE ALLOWS FOR VARIOUS VARIABLE POSITIONS IN FILE.  SEARCHES NVU$(*).
100   ! SPLOTF GRAPHICS CRT OR HP-9872A.  QUICKER POLYNOMIAL PLOTTING. JHD.
110   ! SPLOTG NOV 28 79. FIXED ERROR IN VARIABLE NAME SEARCH. JHD.
120   ! SPLOTH JAN 23 80. SPECIAL NSCAN=500 TO ALLOW FOR ERROR IN FRONTS DXPROG
130   ! SPLOTI MAY 7 80.  FOR NEW XTVP FORMAT.. NOT RIGHT YET. JHD.
140   ! SPLOTJ ... ERIC KUNZE FIXED FROM SPLOTI.
150   ! SPLOTM ... ALSO ROTATES THE FITS. RECEIVED FROM ERIC KUNZE AS FITPRO.
160   ! SPLOTN ... MODIFIED TO MAKE VIEW GRAPHS OF WENSTRANDS 8 WITH OUR 191,...
170   ! SPLOTO ... APR 8 81, FIXED INPUT STATEMENTS TO CHECK PARAMETERS.
180    !
190 !
200 !
210 !
220 !
230 ! SPLOT accepts standard-format processed XTVP files for some specialized
240 ! processing and then plotting to assist scientific analysis.  It will plot
250 ! several profiles with the same processing on the same page for easy
260 ! comparison.
270 !     Usually the profiles are fit to a low-degree polynomial
280 ! to remove the low wave-number components.  The fits or residuals
290 ! are then plotted instead.
300 !     The residuals can be rotated to a common time according to the
310 ! local inertial period (12 hours divided by the sine of the latitude).
320 ! This allows one to attempt to view a time series or section as if it
330 ! had occured instantaneously.
340 !     Cartesian or polar plots are available as are various plotters.
350 !
360 ! One specifies the following parameters with defaults in ().
370 !  . variable names (U,V) for processing.
380 !  . velocity error limit (2 cm/s) for use in eliminating noisey data.
390 !  . degree of polynomial fit (0).
400 !  . plot residues or fits (R).
410 !  . cartesian or polar plots (C).
420 !  . whether or not to rotate the plots (N).
430 !  . pen number to use (0).
440 !  . whether to label the plot (Y).  Don't label overlays of fits on data.
450 !  . tic size (25.4mm).  the plots are 10 cm/s/tic and 200m/tic.  The
460 !    default tic size is for 15 by 10 inch paper.  To use the 10 by 7
470 !    inch paper use a tic size of 25.4*7/10=17.78.  When using the GRAPHICS
480 !    plotter the tic size is adjusted to fit exactly.
490 !  . size of paper in tics. (15,10).
500 !  . size of paper in inches - user can choose three types.  Position
510 !    view graphs up from the bottom somewhat.
520 !  . file names until a blank name.
530 !  . if rotating then input the time of the profile.
540 !  . offsets for each component (4,4 tics).  This is in addition to the
```

```
550 !    normal incrementing of two tics to the right for each profile.  Use
560 !    the default value of 4,4 the first time through and refine it later.
570 !  . specify the amount at the top of all profiles to zap in meters.
580 !
590 ! now the program should continue by itself and print each drop header as
600 ! they are read from mass storage.  If a file cannot be found then the
610 ! program will prompt for another disc or tape.  Plots are drawn as the
620 ! data is processed.
630 !
640 !
650 !
660   PRINTER IS 0
670   OPTION BASE 1
680   OVERLAP
690   STANDARD
700   DEG
710  !
720      DIM File$(16),Offqu(16),Offiv(16)
730      DIM Comment$[160],Rmslabel$[80],Now(5)
740      DIM Param(100),Nvu$(9),A(4),Drot(5),Thr(16),Tmin(16)
750      SHORT F(4,500),Fav(4,50)
760      SHORT Wav(50),Dav(50,4)
770      SHORT D(500,9),W(500),Residue(500)
780   !
790   !  PRINT PAGE
800      MAT W=CON
810      OUTPUT 9;"R"
820      ENTER 9;R$
830      R$=VAL$(Year)&":"&R$
840      PRINT Progrev$,"RUN DATE/TIME=";R$
850  !
860   DIM Var$(3:4)
870   IF LEN(Var$(3))=0 THEN Var$(3)="U"
880   IF LEN(Var$(4))=0 THEN Var$(4)="V"
890   DISP "VARIABLE NAMES (DEFAULT= ";Var$(3);",";Var$(4);")";
900   INPUT Var$(3),Var$(4)
910   PRINT "VARIABLE NAMES USED ARE ";Var$(3);",";Var$(4)
920 !
930   IF Veler=0 THEN Veler=2
940   DISP "VELOCITY ERROR LIMIT (DEFAULT=";Veler;")";
950   INPUT Veler
960   IF Veler<=0 THEN 940
970   !
980   PRINT "VELOCITY ERROR LIMIT=";Veler
990   Rmslabel$="VELOCITY ERROR LIMIT="&VAL$(Veler)
1000 !
1010  IF LEN(Fit$)=0 THEN Fit$="Y"
1020  DISP "IS DATA TO BE FITTED TO POLYNOMIAL (Y OR N; DEFAULT= ";Fit$;")";
1030  INPUT Fit$
1040  IF (Fit$<>"Y") AND (Fit$<>"N") THEN 1020
1050 !
1060  IF Fit$="Y" THEN Fit
1070     PRINT "DATA NOT FITTED TO POLYNOMIAL."
1080     Rot$="N"             !NO FIT THEN NO ROTATION
1090     Polar$="C"           ! NO ROTATION THEN USE CARTISIAN COORD.
1100     GOTO 1650
```

```
1110 !
1120 Fit:!
1130   DISP "DEGREE OF POLYNOMIAL FIT (0=CONST,1=LIN,2=QUAD,3=CUBIC; DEFAULT=";D
egree;")";
1140   INPUT Degree
1150   IF (Degree<0) OR (Degree>3) THEN 1130
1160   !
1170   PRINT "DATA FITTED TO A POLYNOMIAL OF DEGREE ";Degree
1180   Fitlabel$="FIT TO DEGREE "&VAL$(Degree)
1190   Order=Degree+1
1200 !
1210   IF LEN(Plot$)=0 THEN Plot$="R"
1220   DISP "PLOT FIT OR RESIDUE (F OR R; DEFAULT=";Plot$;" )";
1230   INPUT Plot$
1240   IF (Plot$<>"F") AND (Plot$<>"R") THEN 1220
1250   !
1260   IF Plot$="F" THEN Plttyp$="FIT"
1270   IF Plot$="R" THEN Plttyp$="RESIDUE"
1280   PRINT "PLOT THE ";Plttyp$
1290 !
1300   IF LEN(Polar$)=0 THEN Polar$="C"
1310   DISP "CARTESIAN OR POLAR PLOTS (C OR P; DEFAULT=";Polar$;" )";
1320   INPUT Polar$
1330   IF (Polar$<>"C") AND (Polar$<>"P") THEN 1310
1340   IF Polar$="C" THEN PRINT "PLOTS ARE CARTESIAN"
1350   IF Polar$="P" THEN PRINT "PLOTS ARE POLAR"
1360 !
1370   IF LEN(Rot$)=0 THEN Rot$="N"
1380   DISP "ARE PROFILES TO BE ROTATED (Y OR N; DEFAULT=";Rot$;" )";
1390   INPUT Rot$
1400   IF (Rot$<>"Y") AND (Rot$<>"N") THEN 1380
1410 !
1420   IF Rot$="Y" THEN 1460
1430    !
1440     PRINT "PROFILES ARE NOT ROTATED"
1450     GOTO 1650
1460 !
1470      DISP "ENTER REFERENCE TIME (hr,min; DEFAULT=";T0hr;T0min;" )";
1480      INPUT T0hr,Tomin
1490 !
1500      DISP "ROTATION PERIOD (hr.decimal; DEFAULT=";Rotper;")";
1510      INPUT Rotper
1520      IF Rotper=0 THEN 1500
1530 !
1540      Blankhr$=Blankmin$=""
1550      IF (LEN(VAL$(T0hr))=1) AND (LEN(VAL$(T0min))=1) THEN Blankhr$=Blankmin
$="0"
1560      IF (LEN(VAL$(T0hr))>1) AND (LEN(VAL$(T0min))=1) THEN Blankmin$="0"
1570      IF (LEN(VAL$(T0hr))=1) AND (LEN(VAL$(T0min))>1) THEN Blankhr$="0"
1580      Rotlabel$="ROTATED TO "&Blankhr$&VAL$(T0hr)&":"&Blankmin$&VAL$(T0min)
1590 !
1600      PRINT "THE RESIDUE PROFILES WERE ROTATED BASED ON REF.TIME OF ";T0hr;"
hr ";T0min;"min "
1610      PRINT "  FOR A ROTATION PERIOD OF ";Rotper
1620      PRINT Rotlabel$
1630 !
```

```
1640      Pen=VAL(Pen$)
1650      DISP "PEN NUMBER TO BE USED (1,2,3 OR 4; 0 FOR ALL; DEFAULT=";Pen;" )"
;
1660      INPUT Pen
1670      IF (Pen<0) OR (Pen>4) THEN 1650
1680      Pen$=VAL$(Pen)
1690      !
1700      PRINT "A PLOT OF THE ";Plttyp$;" WAS MADE USING PEN #";Pen$
1710 !
1720      IF LEN(Label$)=0 THEN Label$="Y"
1730      DISP "LABEL PLOT (Y OR N; DEFAULT=";Label$;" )";
1740      INPUT Label$
1750      IF (Label$<>"Y") AND (Label$<>"N") THEN 1730
1760 !
1770      IF Label$="N" THEN PRINT "PLOT IS NOT LABELLED."
1780      IF Label$="Y" THEN PRINT "PLOT IS LABELLED."
1790 !
1800      Ans$="P"
1810 !    DISP "RAW OR PROCESSED DATA INPUT (R OR P; DEFAULT=";Ans$;")";
1820 !    INPUT Ans$
1830      IF (Ans$<>"R") AND (Ans$<>"P") THEN 1810
1840 !
1850      IF Ans$="R" THEN Datatyp$="RAW"
1860      IF Ans$="P" THEN Datatyp$="PROCESSED"
1870      PRINT "INPUT DATA IS ";Datatyp$;"."
1880 !
1890 Plotter_setup: !                                   PLOTTER_SETUP
1900 !
1910   IF Plotter=0 THEN Plotter=2
1920   DISP "GRAPHICS (1), 9872A (2) OR 9872S (3);DEFAULT=";Plotter;")";
1930   INPUT Plotter
1940   IF (Plotter<0) OR (Plotter>3) THEN 1920
1950 !
1960   IF Plotter=0 THEN 2470
1970   !
1980   IF Plotter=1 THEN 2010
1990   DISP "PAPER OR ACETATE FILM (0 OR 1; DEFAULT=";Film;")";
2000   INPUT Film
2010   !
2020   IF Tic=0 THEN Tic=25.4
2030   DISP "TIC SIZE (mm; DEFAULT=";Tic;")";
2040   INPUT Tic
2050   PRINT "TIC SIZE =";Tic;" mm"
2060   !
2070   IF Xtics=0 THEN Xtics=15
2080   IF Ytics=0 THEN Ytics=10
2090   DISP "NUMBER OF XTICS, YTICS (DEFAULT=";Xtics;Ytics;")";
2100   INPUT Xtics,Ytics
2110   IF (Xtics<0) OR (Xtics>100) THEN 2090
2120   IF (Ytics<0) OR (Ytics>100) THEN 2090
2130   !
2140   Xmm=Tic*Xtics
2150   Ymm=Tic*Ytics
2160   PRINT "PLOT WILL BE ";Xmm;"mm";Xmm/25.4;"in WIDE AND ";Ymm;" mm ";Ymm/25.
4;"in HIGH"
```

```
2170   Change$="N"
2180   INPUT "DO YOU WANT TO CHANGE THE SPECS? (Y/N)",Change$
2190   IF Change$="Y" THEN 2020
2200   !
2210   ON Plotter GOTO Graphics,Hp9872a,Hp9872s
2220  !
2230 Hp9872s: !
2240 Hp9872a: !
2250  !
2260    IF Paper=0 THEN Paper=3
2270    IF NOT Film THEN DISP "PAPER TYPE (1=7W,10H. 2=15W,10H. 3=10W,7H,HOLES U
P; DEFAULT=";Paper;")";
2280    IF NOT Film THEN INPUT Paper
2290  !
2300    IF Paper=1 THEN OUTPUT 705 USING "K";"IP600,260,7730,10420"
2310    IF Paper=2 THEN OUTPUT 705 USING "K";"IP600,260,15876,10401"
2320    IF Paper=3 THEN OUTPUT 705 USING "K";"IP77,269,10252,7377"
2330    !
2340    PLOTTER IS "9872A"
2350    !
2360    IF Film THEN OUTPUT 705;"VS10;"  !LIMIT PEN VELOCITY TO 10 CM/S WHEN FIL
M IS USED
2370    IF Pen$<>"0" THEN PEN VAL(Pen$)
2380    IF Label$="Y" THEN FRAME
2390    PEN 0
2400    GOTO 2530
2410    !
2420 Graphics: PLOTTER IS "GRAPHICS"
2430           GRAPHICS
2440           Tic=MIN(184.47/Xtics,149.82/Ytics)
2450           PRINT "GRAPHICS TIC SIZE CHANGED TO";Tic;"mm TO FIT SCREEN"
2460           LIMIT 0,Xtics*Tic,0,Ytics*Tic
2470           MSCALE Tic,Tic
2480           LINE TYPE 3
2490           GRID Tic,Tic
2500           LINE TYPE 1
2510           FRAME
2520           EXIT GRAPHICS
2530      IF Ans$="R" THEN Raw
2540      IF Ans$="P" THEN Proc
2550      !
2560 Raw: !
2570    Zsc=Tic/50            ! 50 SEC PER TIC
2580    Dsc=Tic/(1.25*1016)   ! ABOUT 10 CM/S PER TIC
2590    Plotscx$=VAL$(Tic*20/(2.5*1016)/Dsc)&" cm/s"
2600    Plotscy$=VAL$(Tic/Zsc)&" sec"
2610    GOTO 2700
2620 !
2630 Proc:!
2640    Zsc=Tic/200     ! 200 M PER TIC
2650    Dsc=Tic/10      ! 10 CM/S PER TIC
2660    Plotscx$=VAL$(Tic/Dsc)&" cm/s"
2670    Plotscy$=VAL$(Tic/Zsc)&" m"
2680 !                                       SETUP  FILE NAMES AND PARAMETERS
2690  PRINT "FILE NO.  FILE NAME    TIME HR MIN      U,V OFFSETS (TICS)"
2700  FOR File=1 TO 16
```

```
2710     !
2720     DISP "FILE NAME FOR FILE NUMBER=";File;
2730     EDIT File$(File)
2740    !
2750    IF LEN(File$(File))=0 THEN 3060  ! BLANK INDICATES END OF INPUT LIST
2760    !
2770    File$=File$(File)
2780    IF POS(File$,",") THEN 2840
2790    ASSIGN #1 TO File$(File),Ret
2800    IF Ret=0 THEN 2860
2810      BEEP
2820      DISP "THIS FILE NOT ON THIS DISC.  ";
2830      GOTO 2720
2840    DISP "IMPROPER FILE NAME.  ";
2850    GOTO 2720
2860    !
2870 IF Rot$="N" THEN 2950
2880  !
2890 DISP "ENTER DROP TIME (hr,min; DEFAULT=";Thr(File);Tmin(File);")";
2900 INPUT Thr(File),Tmin(File)
2910  IF (Thr(File)<-1000) OR (Thr(File)>=1000) THEN 2890
2920  IF (Tmin(File)<0) OR (Tmin(File)>=60) THEN 2890
2930  !
2940 IMAGE #,4D,6X,15A,3X,2Z,":",2Z
2950 PRINT USING 2940;File;File$(File);Thr(File);Tmin(File)
2960 !
2970  IF Offqu(File)=0 THEN Offqu(File)=4
2980  IF Offiv(File)=0 THEN Offiv(File)=4
2990 DISP "U, V OFFSET (tics; DEFAULT=";Offqu(File);",";Offiv(File);")";
3000 INPUT Offqu(File),Offiv(File)
3010 PRINT USING 3020;Offqu(File);Offiv(File)
3020  IMAGE 8X,3D.D,    3D.D
3030 !
3040 NEXT File     !*********************************************************
3050 !
3060 Nfile=File-1
3070 !
3080    DISP "ZAP TOP OF PROFILES (meters; DEFAULT=";Zzap;")";
3090    INPUT Zzap
3100    Zzap=-ABS(Zzap)
3110    IF Zzap>1000 THEN 3080
3120    PRINT "TOP";ABS(Zzap);"m OF PROFILES ZAPPED"
3130   !
3140 OUTPUT 9;"R"
3150 ENTER 9;Now$
3160 Now$=VAL$(Year)&":"&Now$
3170 PRINT USING "K";"PLOT MADE ";Now$
3180 !
3190        IF Plotter=1 THEN GRAPHICS
3200 !
3210 ! **********************  START OF FILE LOOP TO PROCESS AND PLOT  ******
3220 !
3230  FOR File=1 TO Nfile
3240     Penuse=VAL(Pen$)
3250     IF Pen$="0" THEN Penuse=(File-1) MOD 4+1
3260     PRINT File;"FILE NAME=";File$(File)
```

```
3270   ASSIGN #1 TO File$(File),Ret
3280   IF Ret=0 THEN 3320
3290     BEEP
3300     EDIT "THIS FILE NOT FOUND ON THIS DISC",File$(File)
3310     GOTO 3270
3320   READ #1,1
3330  READ #1;Drop$,Downtime$,Lat$,Long$
3340  PRINT Drop$,Downtime$,Lat$,Long$
3350  !
3360  READ #1;Comment$
3370  PRINT Comment$
3380  !
3390  READ #1;Oldprog$,Oldfile$,Created$
3400  PRINT USING 3410;Oldprog$,Oldfile$,Created$
3410  IMAGE "CREATED BY ",K," FROM FILE ",K,", ON ",K
3420  !
3430  READ #1;Nvar,Nscan,Bad,Nparam
3440  REDIM Param(Nparam),Nvu$(Nvar),D(Nscan,Nvar)
3450  READ #1;Param(*),Nvu$(*),D(*)
3460  !
3470  FOR I=1 TO Nscan
3480    IF D(I,9)<Veler THEN 3510
3490    D(I,3)=Bad
3500    D(I,4)=Bad
3510  NEXT I
3520   !
3530  FOR V=3 TO 4                   ! SEARCH FOR VARIABLES BY NAME
3540     FOR L=1 TO Nvar
3550     IF Nvu$(L)[1;LEN(Var$(V))]=Var$(V) THEN 3650
3560     NEXT L
3570       BEEP
3580       EXIT GRAPHICS
3590       PRINTER IS 16
3600       PRINT Nvu$(*)
3610       PRINTER IS 0
3620       EDIT "CAN'T FIND VARIABLE BELOW.  CHOOSE NAME FROM ABOVE LIST",Var$(
V)
3630       GRAPHICS
3640       GOTO 3540
3650     Var(V)=L
3660  NEXT V
3670   DIM Var(9)
3680 !
3690  IF Ans$="R" THEN Dz=-.5
3700 !
3710  FOR V=3 TO 4
3720   FOR I=1 TO Nscan
3730    IF D(I,1)<Zzap THEN 3750
3740     D(I,V)=Bad
3750    NEXT I
3760   NEXT V
3770  LINE TYPE 1
3780  CSIZE 2
3790    IF Plotter=1 THEN CSIZE 2.8
3800  LORG 9
3810  LDIR 0
```

```
3820  MSCALE 0,0
3830  IF Label$="N" THEN 3970
3840  IF File>1 THEN 3970
3850    PEN 1
3860    SETGU
3870    Xgdumax=100*MAX(1,RATIO)
3880    Ygdumax=100*MAX(1,1/RATIO)
3890    MOVE .99*Xgdumax,.99*Ygdumax
3900    IMAGE 3(ZZ,X),2(ZZ,":"),ZZ
3910    LABEL USING "K";Now$
3920    LABEL USING "K";Fitlabel$
3930 !  LABEL USING "K";Rmslabel$
3940    IF Rot$="N" THEN 3960
3950    LABEL USING "K";Rotlabel$
3960    SETUU
3970 Xoff=2*Tic*(1+File)-1.5*Tic   !MOVE EACH PLOT OVER 1 TIC STARTING AT 2
3980  MSCALE Xoff,0  ! PLOT IN mm
3990  MOVE 0,2
4000  LORG 4
4010  PEN Penuse
4020  IF Label$="Y" THEN LABEL USING "K";File$(File)
4030  PEN 0
4040  !                              START OF Var LOOP #1
4050  IF Fit$="N" THEN 4700    !SKIP OVER FITTING PORTION
4060  !
4070  FOR I=1 TO Nscan          ! SET UP FITTING FUNCTIONS
4080  F(1,I)=1
4090  F(2,I)=I
4100  F(3,I)=I^2
4110  F(4,I)=I^3
4120  NEXT I
4130  !                            AVERAGE FITTING FUNCTIONS
4140  Nblocks=30
4150  REDIM Fav(4,Nblocks),Wav(Nblocks),Dav(Nblocks,4)
4160  Blocksize=Nscan DIV Nblocks
4170      FOR J=1 TO Nblocks
4180        FOR V=1 TO Order
4190          Fav=0
4200          FOR L=1 TO Blocksize
4210            I=(J-1)*Blocksize+L
4220            Fav=Fav+I^(V-1)
4230          NEXT L
4240          Fav(V,J)=Fav/Blocksize
4250        NEXT V
4260      NEXT J
4270 !                            AVERAGE WEIGHTING FUNCTION W TO WAV
4280      FOR J=1 TO Nblocks
4290      Wav=0
4300        FOR K=1 TO Blocksize
4310        I=(J-1)*Blocksize+K
4320        Wav=Wav+W(I)
4330        NEXT K
4340        Wav(J)=Wav/Blocksize
4350      NEXT J
4360  !                               AVERAGE DATA D TO DAV
4370    MAT Dav=(Bad)
```

```
4380     FOR V=3 TO 4
4390     Var=Var(V)
4400       FOR J=1 TO Nblocks
4410       Dav=0
4420       Nav=0
4430         FOR K=1 TO Blocksize
4440           I=(J-1)*Blocksize+K
4450           D=D(I,Var)
4460           IF D=Bad THEN 4490
4470             Dav=Dav+D
4480             Nav=Nav+1
4490         NEXT K
4500         IF Nav THEN Dav(J,V)=Dav/Nav
4510       NEXT J
4520     NEXT V
4530 !                            OBTAIN FIT FROM AVERAGED DATA,FIT,WEIGHTING
4540   FOR V=3 TO 4
4550       Var=Var(V)
4560       CALL Lsqw2(A(*),V,Nblocks,Order,Bad,Ngood,1,Dav(*),Wav(*),Fav(*))
4570       PRINT "AVERAGE FIT. NBLOCKS=";Nblocks;
4580       PRINT USING "K,X";"A=";A(*)
4590   !
4600     FOR I=1 TO Nscan
4610       IF D(I,Var)=Bad THEN 4680
4620       Fit=0
4630       FOR J=1 TO Order          ! FORM FIT
4640         Fit=Fit+F(J,I)*A(J)
4650       NEXT J
4660       IF Plot$="F" THEN D(I,Var)=Fit
4670       IF Plot$="R" THEN D(I,Var)=D(I,Var)-Fit
4680     NEXT I
4690   NEXT V
4700   !                          END OF Var LOOP #1
4710   !                          START OF Var LOOP #2: DATA IS PLOTTED
4720   PEN Penuse
4730   FOR V=3 TO 4
4740     Var=Var(V)
4750     V3=Var(3)
4760     V4=Var(4)
4770     Yoff=Tic*5*(5-V)         ! PUT U ABOVE V, EACH 5 TICS HIGH
4780     Offset=Offqu(File)*Tic      !OFFSET Q(U)
4790     IF V=4 THEN Offset=Offiv(File)*Tic     ! OFFSET I(V)
4800     LORG 3
4810     MSCALE 0,Yoff
4820     LINE TYPE 1
4830     IF File>1 THEN 5080
4840     IF Label$="N" THEN 5080
4850     MOVE 2,-2
4860     LDIR 0
4870     IF Polar$="C" THEN 4910
4880       Nvu$(V3)="SPEED"
4890       Nvu$(V4)="PHASE"
4900       IF V=4 THEN Plotscx$="200 deg"
4910     LABEL USING "K";Nvu$(Var)
4920     MOVE Tic/10,-3*Tic/10
4930     DRAW Tic/10,-4*Tic/10
```

```
4940      DRAW 11*Tic/10,-4*Tic/10
4950      DRAW 11*Tic/10,-3*Tic/10
4960      MOVE 6*Tic/10,-5*Tic/10
4970      LORG 6
4980      LDIR 0
4990      LABEL USING "K";Plotscx$
5000      MOVE 2*Tic/10,-2*Tic
5010      DRAW Tic/10,-2*Tic
5020      DRAW Tic/10,-3*Tic
5030      DRAW 2*Tic/10,-3*Tic
5040      MOVE 3*Tic/10,-2.5*Tic
5050      LORG 6
5060      LDIR 90
5070      LABEL USING "K";Plotscy$
5080      IF Pen$="0" THEN 5110
5090        IF File MOD 2=1 THEN LINE TYPE 1
5100        IF File MOD 2=0 THEN LINE TYPE 5,1
5110      P=-2
5120      MSCALE Xoff,Yoff
5130 !
5140 ! PLOT THE DATA
5150      Slide=4*Tic
5160      Ngood=Sr=Ssr=Srw=Ssrw=0
5170      IF Rot$="N" THEN 5230
5180      !
5190      Angle=(Thr(File)-T0hr+(Tmin(File)-T0min)/60)*360/Rotper
5200      IF Ans$="R" THEN Angle=-1*Angle      ! FOR RAW DATA QUAD-PHASE CORRESPON
DS TO EAST, HENCE THE NEED TO CHANGE ANGLE
5210      Cos=COS(Angle)
5220      Sin=SIN(Angle)
5230        FOR Scan=1 TO Nscan
5240          D=D(Scan,Var)
5250          D3=D(Scan,V3)
5260          D4=D(Scan,V4)
5270          IF (D3<>Bad) AND (D4<>Bad) THEN 5310
5280          D3=D4=Bad
5290          P=-2
5300          GOTO 5610
5310          Y=D(Scan,1)*Zsc
5320          IF (Rot$="N") OR (V=4) THEN 5380
5330          Drot(3)=D3*Cos-D4*Sin
5340          Drot(4)=D3*Sin+D4*Cos
5350          D=Drot(Var)
5360          D3=Drot(3)
5370          D4=Drot(4)
5380          IF Polar$="C" THEN 5510
5390          IF Ans$="R" THEN D3=-D3
5400          D=SQR(D3^2+D4^2)
5410          IF V=3 THEN 5510
5420          D=ATN(D3/D4)
5430          IF (D3<0) AND (D4>0) THEN D=D+180
5440          IF (D3<0) AND (D4<0) THEN D=D-180
5450          X=D*Tic/200             ! 200 DEG PER TIC FOR PHASE
5460          IF ABS(D-Dlast)<200 THEN 5520
5470          Dlast=D
5480          P=-2
```

```
5490          GOTO 5610
5500      !
5510          X=D*Dsc-Slide+Offset        ! OFFSET TO LEFT BY 4 TICS PLUS DESIRED
OFFSET
5520          Dlast=D
5530          Ngood=Ngood+1
5540          Sr=Sr+D
5550          Ssr=Ssr+D^2
5560          Xw=D*W(Scan)
5570          Srw=Srw+Xw
5580          Ssrw=Ssrw+Xw^2
5590          PLOT X,Y,P
5600          P=-1
5610      !
5620          D(Scan,3)=D3
5630          D(Scan,4)=D4
5640        NEXT Scan
5650   !
5660      Avg=Sr/Ngood
5670      Sig=SQR(Ssr/Ngood-Avg^2)
5680      Avgw=Srw/Ngood
5690      Sigw=SQR(Ssrw/Ngood-Avgw^2)
5700      IF Ans$="P" THEN 5740
5710      Comptyp$="QUAD-PHASE"
5720      IF V=4 THEN Comptyp$="IN-PHASE"
5730      GOTO 5800
5740      Comptyp$="U COMP"
5750      IF V=4 THEN Comptyp$="V COMP"
5760      IF File>1 THEN 5800       !PRINT HEADING ONCE
5770      IF V>3 THEN 5800
5780      PRINT "INPUT FILE,VARIABLE,NO. OF GOOD PTS,AVE.,STD. DEV. BASED ON GOOD
 PTS"
5790      IMAGE 4X,6A,4X,10A,4X,DDD,DDDD.DDD,4X,DDD.DDD
5800      PRINT USING 5790;File$(File),Comptyp$,Ngood,Avgw,Sigw
5810    NEXT V
5820    PEN 0
5830 NEXT File
5840 PEN 0
5850 BEEP
5860 ! IF Plotter=1 THEN PRINT PAGE
5870 ! IF Plotter=1 THEN DUMP GRAPHICS
5880 ! IF Plotter=1 THEN PRINT PAGE
5890 IF Plotter=1 THEN EXIT GRAPHICS
5900 DISP Progrev$;
5910 INPUT " FINISHED.  0 TO STOP,  1 TO CHANGE OFFSETS AND  REPLOT",Control
5920    ON Control+1 GOTO 5930,Plotter_setup
5930    STOP
5940    !
5950 END
5960 ! **********************************************
5970 SUB Lsqw2(A(*),Var,Nscan,Order,Bad,Ngood,I1,SHORT D(*),W(*),F(*))
5980 OPTION BASE 1
5990 DIM C(Order,Order),Ci(Order,Order),B(Order)
6000 Ngood=0
6010 FOR I=1 TO Nscan
6020 D=D(I+I1-1,Var)
```

```
6030 IF D=Bad THEN 6120
6040 Ngood=Ngood+1
6050 FOR J=1 TO Order
6060 Fw=F(J,I)*W(I)
6070 B(J)=B(J)+Fw*D
6080 FOR K=1 TO J
6090 C(J,K)=C(J,K)+Fw*F(K,I)
6100 NEXT K
6110 NEXT J
6120 NEXT I
6130 FOR J=1 TO Order
6140 FOR K=1 TO J
6150 C(K,J)=C(J,K)
6160 NEXT K
6170 NEXT J
6180 MAT Ci=INV(C)
6190 MAT A=Ci*B
6200 SUBEND
6210 END
```

Program CROSS, Sample Run

CROSS is a program that computes cross correlation, structure functions and coherences between pairs of profiles. The operator can select the number of profiles, number of variables in each profile, plotter to use, depth interval and depth interpolation interval.

The operator sets up the program in advance for many operations; the computer can then be left unattended. This program can be very time consuming, depending on the options selected.

The following is an example of computing structure functions of seven profiles for both east and north components.

```
PRINTER ? (0=THERMAL, 16=CRT)
0
CROSSE SEPT 24 80   RUN DATE AND TIME = 81:04:08:23:41:27
NUMBER OF VARIABLES ?
2
NUMBER OF VARIABLES = 2
NUMBER OF FILES ?
7
NUMBER OF FILES = 7
PLOTTER ? (0=NONE, 1=GRAPHICS, 2=9872A)
0
PLOTTER$=NONE
PROCESSING OPTION? (1=CROSS CORRELATION, 2=STRUCTURE FUNCTION, 3=COHERANCE)
2
PROCESSING OPTION=STRUCTURE
FIRST,LAST DEPTH TO PROCESS ?
200,800
FIRST,LAST DEPTH TO PROCESS =-200 -800
NUMBER OF POINTS PER PIECE ?
50
NUMBER OF POINTS PER PIECE = 50
NUMBER OF PIECES?
2
NUMBER OF PIECES= 2
TOTAL NUMBER OF POINTS USED= 100
DEPTH INCREMENT=-6.06060606061
DEPTH PER PIECE=-296.96969697
MAX DEPTH LAG ?
20
MAX DEPTH LAG = 20
MAXIMUM RMSERR ALLOWED FOR XTVP DATA?
3
MAXIMUM RMSERR ALLOWED FOR XTVP DATA= 3
TYPE FILE NAME FOR FILE No. 1

82P
WHICH 2 VARIABLE No.s TO PROCESS?
```

```
3,4
VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)
9
FILE No.= 1   FILENAME=82P  VARIABLES=U, V, VELERR.
TYPE FILE NAME FOR FILE No. 2

83P
WHICH 2 VARIABLE No.s TO PROCESS?

3,4
VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)
9
FILE No.= 2   FILENAME=83P  VARIABLES=U, V, VELERR.
TYPE FILE NAME FOR FILE No. 3

84P
WHICH 2 VARIABLE No.s TO PROCESS?

U,V
WHICH 2 VARIABLE No.s TO PROCESS?

U,V
WHICH 2 VARIABLE No.s TO PROCESS?

3,4
VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)
9
FILE No.= 3   FILENAME=84P  VARIABLES=U, V, VELERR.

TYPE FILE NAME FOR FILE No. 4

85P
WHICH 2 VARIABLE No.s TO PROCESS?

3,4
VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)
9
FILE No.= 4   FILENAME=85P  VARIABLES=U, V, VELERR.
TYPE FILE NAME FOR FILE No. 5

86P
WHICH 2 VARIABLE No.s TO PROCESS?

3,4
VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)
9
FILE No.= 5   FILENAME=86P  VARIABLES=U, V, VELERR.
TYPE FILE NAME FOR FILE No. 6

87P
WHICH 2 VARIABLE No.s TO PROCESS?

3,4
VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)
9
FILE No.= 6   FILENAME=87P  VARIABLES=U, V, VELERR.
TYPE FILE NAME FOR FILE No. 7
```

```
88P
WHICH 2 VARIABLE No.s TO PROCESS?

3,4
VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)
9
FILE No.= 7   FILENAME=88P  VARIABLES=U, V, VELERR.
NUMBER OF SETS OF COMBINATIONS ?
3
NUMBER OF SETS OF COMBINATIONS = 3
No. FILES IN SET No. 1 ?

3
WHICH 3 FILE No.s FOR SET No. 1 ?

1,2,3
SET= 1 HAS FILE No.s: 1 ,  2 ,  3 .
No. FILES IN SET No. 2 ?

4
WHICH 4 FILE No.s FOR SET No. 2 ?

3,4,5,6
SET= 2 HAS FILE No.s: 3 ,  4 ,  5 ,  6 .
No. FILES IN SET No. 3 ?

3
WHICH 3 FILE No.s FOR SET No. 3 ?

1,2,7
SET= 3 HAS FILE No.s: 1 ,  2 ,  7 .

SET FILENO FILENAME           VARIABLE
  1    1    82P               U
       2    83P               U
DEPTH RANGE    AV1      AV2 ZLAG   AVDIF  RMSDIF  RMSMIN  OK1  OK2   RMS1   RMS2
 (meters)                   (m)                           fraction

INTERPOLATING

PROCESSING STRUCTURE

 -200 -497   -9.23   -9.77  -18    -.14    1.65    1.65 1.00 1.00    1.7    1.4
INTERPOLATING

PROCESSING STRUCTURE

 -497 -794   -6.48   -5.22    6     .12    2.12    2.12 1.00 1.00    3.5    4.4

SET FILENO FILENAME           VARIABLE
  1    1    82P               V
       2    83P               V
DEPTH RANGE    AV1      AV2 ZLAG   AVDIF  RMSDIF  RMSMIN  OK1  OK2   RMS1   RMS2
 (meters)                   (m)                           fraction
INTERPOLATING
```

```
PROCESSING STRUCTURE

 -200 -497    -2.92     4.78  -18      .40     2.51     2.51 1.00 1.00     3.5     1.7
INTERPOLATING

PROCESSING STRUCTURE

 -497 -794    -7.31      .18   -6      .12     2.93     2.93 1.00 1.00     2.6     2.1

SET FILENO FILENAME             VARIABLE
  1    1     82P                U
       3     84P                U
DEPTH RANGE      AV1      AV2 ZLAG    AVDIF   RMSDIF   RMSMIN   OK1  OK2    RMS1    RMS2
 (meters)                      (m)                             fraction
INTERPOLATING

PROCESSING STRUCTURE

 -200 -497    -9.23   -12.66   18      .34     2.72     2.72 1.00 1.00     1.7     2.1
INTERPOLATING

PROCESSING STRUCTURE

 -497 -794    -6.48    -5.49    6      .13     2.73     2.73 1.00 1.00     3.5     4.2

SET FILENO FILENAME             VARIABLE
  1    1     82P                V
       3     84P                V
DEPTH RANGE      AV1      AV2 ZLAG    AVDIF   RMSDIF   RMSMIN   OK1  OK2    RMS1    RMS2
 (meters)                      (m)                             fraction
INTERPOLATING

PROCESSING STRUCTURE

 -200 -497    -2.92     6.72  -18      .51     2.77     2.77 1.00 1.00     3.5     1.8
INTERPOLATING

PROCESSING STRUCTURE

 -497 -794    -7.31     2.38  -18      .38     3.43     3.43 1.00 1.00     2.6     2.9

SET FILENO FILENAME             VARIABLE
  1    2     83P                U
       3     84P                U
DEPTH RANGE      AV1      AV2 ZLAG    AVDIF   RMSDIF   RMSMIN   OK1  OK2    RMS1    RMS2
 (meters)                      (m)                             fraction
INTERPOLATING

PROCESSING STRUCTURE

 -200 -497    -9.77   -12.66  -18      .00     3.02     3.02 1.00 1.00     1.4     2.1
INTERPOLATING

PROCESSING STRUCTURE

 -497 -794    -5.22    -5.49    0     -.00     2.24     2.24 1.00 1.00     4.4     4.2
```

```
SET FILENO FILENAME          VARIABLE
  1   2     83P                V
      3     84P                V
DEPTH RANGE     AV1      AV2 ZLAG    AVDIF   RMSDIF   RMSMIN  OK1  OK2    RMS1    RMS2
 (meters)                     (m)                             fraction
INTERPOLATING

PROCESSING STRUCTURE

 -200 -497    4.78     6.72   18     -.10     1.84     1.84 1.00 1.00     1.7     1.8
INTERPOLATING
 -497 -794     .18     2.38  -12      .21     3.13     3.13 1.00 1.00     2.1     2.9

SET FILENO FILENAME          VARIABLE
  2   3     84P                U
      4     85P                U
DEPTH RANGE     AV1      AV2 ZLAG    AVDIF   RMSDIF   RMSMIN  OK1  OK2    RMS1    RMS2
 (meters)                     (m)                             fraction
 -200 -497  -12.66   -15.18    0     -.00     2.74     2.74 1.00 1.00     2.1     2.0
 -497 -794   -5.49    -8.61  -18     -.65     2.24     2.24 1.00 1.00     4.2     3.4

SET FILENO FILENAME          VARIABLE
  2   3     84P                V
      4     85P                V
DEPTH RANGE     AV1      AV2 ZLAG    AVDIF   RMSDIF   RMSMIN  OK1  OK2    RMS1    RMS2
 (meters)                     (m)                             fraction
 -200 -497    6.72     2.84    6     -.13     3.42     3.42 1.00 1.00     1.8     3.7
 -497 -794    2.38    -3.64  -18     -.04     3.37     3.37 1.00 1.00     2.9     2.0

SET FILENO FILENAME          VARIABLE
  2   3     84P                U
      5     86P                U
DEPTH RANGE     AV1      AV2 ZLAG    AVDIF   RMSDIF   RMSMIN  OK1  OK2    RMS1    RMS2
 (meters)                     (m)                             fraction
 -200 -497  -12.66   -13.81   18     -.15     2.89     2.89 1.00 1.00     2.1     1.9
 -497 -794   -5.49    -5.63   18      .64     2.53     2.53 1.00 1.00     4.2     4.5

SET FILENO FILENAME          VARIABLE
  2   3     84P                V
      5     86P                V
DEPTH RANGE     AV1      AV2 ZLAG    AVDIF   RMSDIF   RMSMIN  OK1  OK2    RMS1    RMS2
 (meters)                     (m)                             fraction
 -200 -497    6.72    -6.32   18     -.78     4.20     4.20 1.00 1.00     1.8     5.2
 -497 -794    2.38   -10.18  -12      .02     3.40     3.40 1.00 1.00     2.9     2.1

SET FILENO FILENAME          VARIABLE
  2   3     84P                U
      6     87P                U
DEPTH RANGE     AV1      AV2 ZLAG    AVDIF   RMSDIF   RMSMIN  OK1  OK2    RMS1    RMS2
 (meters)                     (m)                             fraction
 -200 -497  -12.66   -15.90   18      .15     3.79     3.79 1.00 1.00     2.1     2.4
 -497 -794   -5.49    -5.27  -18     -.74     2.77     2.77 1.00 1.00     4.2     3.1

SET FILENO FILENAME          VARIABLE
  2   3     84P                V
      6     87P                V
DEPTH RANGE     AV1      AV2 ZLAG    AVDIF   RMSDIF   RMSMIN  OK1  OK2    RMS1    RMS2
```

DEPTH RANGE (meters)	AV1	AV2	ZLAG (m)	AVDIF	RMSDIF	RMSMIN	OK1 fraction	OK2	RMS1	RMS2
-200 -497	6.72	-.26	18	.12	2.71	2.71	1.00	1.00	1.8	2.6
-497 -794	2.38	.94	6	-.12	3.51	3.51	1.00	1.00	2.9	2.2

SET	FILENO	FILENAME	VARIABLE
2	4	85P	U
	5	86P	U

DEPTH RANGE (meters)	AV1	AV2	ZLAG (m)	AVDIF	RMSDIF	RMSMIN	OK1 fraction	OK2	RMS1	RMS2
-200 -497	-15.18	-13.81	-12	-.19	1.92	1.92	1.00	1.00	2.0	1.9
-497 -794	-8.61	-5.63	0	.00	2.25	2.25	1.00	1.00	3.4	4.5

SET	FILENO	FILENAME	VARIABLE
2	4	85P	V
	5	86P	V

DEPTH RANGE (meters)	AV1	AV2	ZLAG (m)	AVDIF	RMSDIF	RMSMIN	OK1 fraction	OK2	RMS1	RMS2
-200 -497	2.84	-6.32	-18	.76	2.51	2.51	1.00	1.00	3.7	5.2
-497 -794	-3.64	-10.18	-6	-.06	2.35	2.35	1.00	1.00	2.0	2.1

SET	FILENO	FILENAME	VARIABLE
2	4	85P	U
	6	87P	U

DEPTH RANGE (meters)	AV1	AV2	ZLAG (m)	AVDIF	RMSDIF	RMSMIN	OK1 fraction	OK2	RMS1	RMS2
-200 -497	-15.18	-15.90	6	.20	2.70	2.70	1.00	1.00	2.0	2.4
-497 -794	-8.61	-5.27	0	.00	2.41	2.41	1.00	1.00	3.4	3.1

SET	FILENO	FILENAME	VARIABLE
2	4	85P	V
	6	87P	V

DEPTH RANGE (meters)	AV1	AV2	ZLAG (m)	AVDIF	RMSDIF	RMSMIN	OK1 fraction	OK2	RMS1	RMS2
-200 -497	2.84	-.26	12	.05	2.62	2.62	1.00	1.00	3.7	2.6
-497 -794	-3.64	.94	-18	.16	2.70	2.70	1.00	1.00	2.0	2.2

SET	FILENO	FILENAME	VARIABLE
2	5	86P	U
	6	87P	U

DEPTH RANGE (meters)	AV1	AV2	ZLAG (m)	AVDIF	RMSDIF	RMSMIN	OK1 fraction	OK2	RMS1	RMS2
-200 -497	-13.81	-15.90	18	.32	2.28	2.28	1.00	1.00	1.9	2.4
-497 -794	-5.63	-5.27	0	.00	3.14	3.14	1.00	1.00	4.5	3.1

SET	FILENO	FILENAME	VARIABLE
2	5	86P	V
	6	87P	V

DEPTH RANGE (meters)	AV1	AV2	ZLAG (m)	AVDIF	RMSDIF	RMSMIN	OK1 fraction	OK2	RMS1	RMS2
-200 -497	-6.32	-.26	18	-.19	3.84	3.84	1.00	1.00	5.2	2.6
-497 -794	-10.18	.94	18	-.21	2.78	2.78	1.00	1.00	2.1	2.2

SET	FILENO	FILENAME	VARIABLE
3	1	82P	U
	2	83P	U

DEPTH RANGE (meters)		AV1	AV2	ZLAG (m)	AVDIF	RMSDIF	RMSMIN	OK1 fraction	OK2	RMS1	RMS2
-200	-497	-9.23	-9.77	-18	-.14	1.65	1.65	1.00	1.00	1.7	1.4
-497	-794	-6.48	-5.22	6	.12	2.12	2.12	1.00	1.00	3.5	4.4

SET	FILENO	FILENAME	VARIABLE
3	1	82P	V
	2	83P	V

DEPTH RANGE (meters)		AV1	AV2	ZLAG (m)	AVDIF	RMSDIF	RMSMIN	OK1 fraction	OK2	RMS1	RMS2
-200	-497	-2.92	4.78	-18	.40	2.51	2.51	1.00	1.00	3.5	1.7
-497	-794	-7.31	.18	-6	.12	2.93	2.93	1.00	1.00	2.6	2.1

SET	FILENO	FILENAME	VARIABLE
3	1	82P	U
	7	88P	U

DEPTH RANGE (meters)		AV1	AV2	ZLAG (m)	AVDIF	RMSDIF	RMSMIN	OK1 fraction	OK2	RMS1	RMS2
-200	-497	-9.23	-15.91	18	.63	2.01	2.01	1.00	1.00	1.7	2.9
-497	-794	-6.48	-4.92	18	-.04	3.58	3.58	1.00	1.00	3.5	2.0

SET	FILENO	FILENAME	VARIABLE
3	1	82P	V
	7	88P	V

DEPTH RANGE (meters)		AV1	AV2	ZLAG (m)	AVDIF	RMSDIF	RMSMIN	OK1 fraction	OK2	RMS1	RMS2
-200	-497	-2.92	-16.71	18	.15	5.99	5.99	1.00	1.00	3.5	3.6
-497	-794	-7.31	-9.48	18	.32	3.30	3.30	1.00	1.00	2.6	3.8

SET	FILENO	FILENAME	VARIABLE
3	2	83P	U
	7	88P	U

DEPTH RANGE (meters)		AV1	AV2	ZLAG (m)	AVDIF	RMSDIF	RMSMIN	OK1 fraction	OK2	RMS1	RMS2
-200	-497	-9.77	-15.91	18	.45	2.49	2.49	1.00	1.00	1.4	2.9
-497	-794	-5.22	-4.92	18	.18	4.24	4.24	1.00	1.00	4.4	2.0

SET	FILENO	FILENAME	VARIABLE
3	2	83P	V
	7	88P	V

DEPTH RANGE (meters)		AV1	AV2	ZLAG (m)	AVDIF	RMSDIF	RMSMIN	OK1 fraction	OK2	RMS1	RMS2
-200	-497	4.78	-16.71	18	.41	4.43	4.43	1.00	1.00	1.7	3.6
-497	-794	.18	-9.48	-12	.00	3.44	3.44	1.00	1.00	2.1	3.8

Listing of Program CROSS

```
10    ! CROSS CORRELATION, STRUCTURE FUNCTION OR COHERANCE BETWEEN TWO PROFILES.
20    ! SPECIALLY MODIFIED TO ZAP U,V OF XTVP PROFILES WHEN RMSERR>MAXERR.
30    ! J. DUNLAP
40    ! SEPT 17 1980 . CROSSD HAS COHERANCE ADDED.
50    ! SEPT 24 1980.  CROSSE HAS COHERANCE WORKING AFTER A FASHION.
60    !
70     Progrev$="CROSSE SEPT 24 80"
80     Year=80
90    !
100    NORMAL
110    STANDARD
120    OVERLAP
130    OPTION BASE 1
140    INPUT "PRINTER ? (0=THERMAL, 16=CRT)",Printer
150    PRINTER IS Printer
160   !
170    OUTPUT 9;"R"
180    ENTER 9;Runtime$
190    Runtime$=VAL$(Year)&":"&Runtime$
200   !
210    DIM Comment$[160],Param(100),Nvu$(9)
220   !
230    DIM Comment1$[160],Param1(100),Nvu1$(9)
240    SHORT D1(500,9)
250   !
260    DIM Param2(100),Nvu2$(9),Comment2$[160]
270    SHORT D2(500,9)
280   !
290    DIM Y1(2000),Y2(2000),R12(100)
300   !
310    PRINT Progrev$,"RUN DATE AND TIME = ";Runtime$
320   !
330    INPUT "NUMBER OF VARIABLES ?",Npair
340    PRINT "NUMBER OF VARIABLES =";Npair
350   !
360    INPUT "NUMBER OF FILES ?",Nfile
370    PRINT "NUMBER OF FILES =";Nfile
380   !
390    DIM Lup(50,3),Lupp(3),File$(50),Luprms(50)
400    REDIM Lup(Nfile,Npair),Lupp(Npair),File$(Nfile),Luprms(Nfile)
410   !
420    INPUT "PLOTTER ? (0=NONE, 1=GRAPHICS, 2=9872A)",Plotter
430      IF Plotter=0 THEN Plotter$="NONE"
440      IF Plotter=1 THEN Plotter$="GRAPHICS"
450      IF Plotter=2 THEN Plotter$="9872A"
460    PRINT "PLOTTER$=";Plotter$
470   !
480    INPUT "PROCESSING OPTION? (1=CROSS CORRELATION, 2=STRUCTURE FUNCTION, 3=C
OHERANCE)",Process
490    IF (Process<1) OR (Process>3) THEN 480
500      IF Process=1 THEN Process$="CROSSCOR"
510      IF Process=2 THEN Process$="STRUCTURE"
520      IF Process=3 THEN Process$="COHERANCE"
530    PRINT "PROCESSING OPTION=";Process$
540   !
```

```
550    INPUT "FIRST,LAST DEPTH TO PROCESS ?",Z1,Z2
560    Z1=-ABS(Z1)
570    Z2=-ABS(Z2)
580    PRINT "FIRST,LAST DEPTH TO PROCESS =";Z1;Z2
590  !
600    INPUT "NUMBER OF POINTS PER PIECE ?",Npp
601    Npp=PROUND(Npp,0)
610    PRINT "NUMBER OF POINTS PER PIECE =";Npp
620  !
630    INPUT "NUMBER OF PIECES?",Npie
631    Npie=PROUND(Npie,0)
640    PRINT "NUMBER OF PIECES=";Npie
650  !
660    Nuse=Npie*Npp
670    Dz=-ABS((Z2-Z1)/(Nuse-1))
680    Zpp=-ABS((Npp-1)*Dz)
690  !
700    PRINT "TOTAL NUMBER OF POINTS USED=";Nuse
710    PRINT "DEPTH INCREMENT=";Dz
720    PRINT "DEPTH PER PIECE=";Zpp
730  !
740    IF (Process$<>"CROSSCOR") AND (Process$<>"STRUCTURE") THEN 780
750    INPUT "MAX DEPTH LAG ?",Zlagmax
760    PRINT "MAX DEPTH LAG =";Zlagmax
770    Nlagmax=ABS((Zlagmax+.1*Dz) DIV Dz)
780  !
790    IF Process$<>"COHERANCE" THEN 850
800    INPUT "NO. FREQ. BANDS TO AVERAGE?",Nband
810    PRINT "NO. FREQ. BANDS TO AVERAGE=";Nband
820  !
830    Nfft=Npp
840    PRINT "NUMBER OF POINTS IN FFT=NUMBER OF POINTS PER PIECE=";Nfft
850  !
860    REDIM R12(-Nlagmax:Nlagmax),Y1(Npp),Y2(Npp)
870  !
880    INPUT "MAXIMUM RMSERR ALLOWED FOR XTVP DATA?",Rmsmaxallowed
890    PRINT "MAXIMUM RMSERR ALLOWED FOR XTVP DATA=";Rmsmaxallowed
900  !
910  ! **************************** GET FILE NAMES AND VARIABLES FOR EACH FILE
920  !
930    FOR File=1 TO Nfile
940      !
950      DISP "TYPE FILE NAME FOR FILE No.";File;
960      EDIT " ",File$(File)
970      !
980      ASSIGN File$(File) TO #1,Ret
990      IF Ret=0 THEN 1040
1000       BEEP
1010       DISP "CANNOT FIND THE FOLLOWING FILE.  PLEASE EDIT OR TRY ANOTHER TAP
E/DISC.";
1020       GOTO 960
1030     !
1040     READ #1,1
1050     READ #1;Drop$,Datetime$,Lat$,Long$,Comment$,Fromrog$,Fromfile$,Created$
1060     READ #1;Nvar,Nscan,Bad,Nparam
1070     REDIM Nvu$(Nvar),Param(Nparam)
```

```
1080      READ #1;Param(*),Nvu$(*)
1090      !
1100      PRINTER IS 16
1110      PRINT "FILE=";File$(File)
1120      PRINT "VARIABLE No.","VARIABLE NAME"
1130      FOR L=1 TO Nvar
1140        PRINT L,Nvu$(L)
1150      NEXT L
1160      PRINTER IS Printer
1170      !
1180      FOR Pair=1 TO Npair
1190        Lupp(Pair)=Lup(File,Pair)
1200      NEXT Pair
1210      !
1220      DISP "WHICH";Npair;"VARIABLE No.s TO PROCESS?";
1230      INPUT "",Lupp(*)
1240      !
1250      FOR Pair=1 TO Npair
1260        IF (Lupp(Pair)<1) OR (Lupp(Pair)>Nvar) THEN 1220
1270        Lup(File,Pair)=Lupp(Pair)
1280      NEXT Pair
1290      !
1300      INPUT "VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)",Luprms(File)
1310      IF (Luprms(File)<0) OR (Luprms(File)>Nvar) THEN 1300
1320      !
1330      PRINT "FILE No.=";File;"  FILENAME=";File$(File);"  VARIABLES=";
1340      FOR Pair=1 TO Npair
1350        PRINT Nvu$(Lup(File,Pair));", ";
1360      NEXT Pair
1370      !
1380      IF Luprms(File) THEN PRINT Nvu$(Luprms(File));"."
1390      IF NOT Luprms(File) THEN PRINT "."
1400    NEXT File
1410    !
1420    !  DETERMINE THE SET BOUNDRIES
1430    !  IN ONE SET ALL THE COMBINATIONS WILL BE USED
1440    !
1450    INPUT "NUMBER OF SETS OF COMBINATIONS ?",Nset
1460    PRINT "NUMBER OF SETS OF COMBINATIONS =";Nset
1470    !
1480    DIM Fileno(50,20),Nfile(20)
1490    REDIM Fileno(Nfile,Nset),Nfile(Nset)
1500    !
1510    FOR Set=1 TO Nset
1520      DISP "No. FILES IN SET No.";Set;"?";
1530      INPUT "",Nfile(Set)
1540      IF (Nfile(Set)<2) OR (Nfile(Set)>Nfile) THEN 1520
1550      !
1560      DIM Filen(20)
1570      REDIM Filen(Nfile(Set))
1580      !
1590      FOR F=1 TO Nfile(Set)
1600        Filen(F)=Fileno(F,Set)
1610      NEXT F
1620      !
1630      DISP "WHICH";Nfile(Set);"FILE No.s FOR SET No.";Set;"?";
```

```
1640      INPUT "",Filen(*)
1650      !                                CHECK FILE No.s
1660      FOR F=1 TO Nfile(Set)
1670        IF (Filen(F)<1) OR (Filen(F)>Nfile) THEN 1630
1680        Fileno(F,Set)=Filen(F)
1690      NEXT F
1700      !
1710      PRINT "SET=";Set;"HAS FILE No.s:";
1720      FOR F=1 TO Nfile(Set)-1
1730        PRINT Fileno(F,Set);", ";
1740      NEXT F
1750      PRINT Fileno(Nfile(Set),Set);"."
1760      !
1770    NEXT Set
1780 !
1790 ! ****************  READ DATA FROM ALL PAIRS OF FILES FROM EACH SET
1800 !
1810 FOR Set=1 TO Nset
1820   FOR File1=1 TO Nfile(Set)-1
1830 !                                          INPUT FILE 1
1840      File1no=Fileno(File1,Set)
1850      File1$=File$(File1no)
1860      ASSIGN File1$ TO #1,Ret
1870      IF Ret=0 THEN 1930
1880        DISP "CANNOT FIND FILE = ";File$(File1);". TRY ANOTHER DISC/TAPE THEN
 PUSH CONT"
1890        BEEP
1900        PAUSE
1910        DISP ""
1920        GOTO 1860
1930      READ #1,1
1940      READ #1;Drop1$,Datetime1$,Lat$,Long1$
1950      READ #1;Comment1$,Fromprog1$,Fromfile1$,Created1$
1960      READ #1;Nvar1,Nscan1,Bad1,Nparam1
1970      REDIM Nvu1$(Nvar1),D1(Nscan1,Nvar1),Param1(Nparam1)
1980      READ #1;Param1(*),Nvu1$(*),D1(*)
1990      !
2000      ! SET DATA BAD WHICH HAVE RMSERR LARGER THAN RMSMAX
2010      ! JUST FOR VARIABLES USED
2020      !
2030      Luprms=Luprms(File1)
2040      IF Luprms=0 THEN 2130
2050        FOR I=1 TO Nscan1
2060          Rms=D1(I,Luprms)
2070          IF Rms<Rmsmaxallowed THEN 2120
2080          FOR Var=1 TO Npair
2090            Lup=Lup(File1,Var)
2100            D1(I,Lup)=Bad1
2110          NEXT Var
2120        NEXT I
2130      !
2140      FOR File2=File1+1 TO Nfile(Set)
2150 !                                        INPUT FILE 2
2160        File2no=Fileno(File2,Set)
2170        File2$=File$(File2no)
2180        ASSIGN File2$ TO #2,Ret
```

```
2190        IF Ret=0 THEN 2250
2200          BEEP
2210          DISP "CANNOT FIND FILE = ";File$(File2);".  TRY ANOTHER TAPE/DISC T
HEN PUSH CONT"
2220          PAUSE
2230          DISP ""
2240          GOTO 2180
2250        READ #2,1
2260        READ #2;Drop2$,Datetime2$,Lat2$,Long2$
2270        READ #2;Comment2$,Fromprog2$,Fromfile2$,Created2$
2280        READ #2;Nvar2,Nscan2,Bad2,Nparam2
2290        REDIM Nvu2$(Nvar2),D2(Nscan2,Nvar2),Param2(Nparam2)
2300        READ #2;Param2(*),Nvu2$(*),D2(*)
2310        !
2320        ! SET DATA BAD WHICH HAVE RMSERR LARGER THAN RMSMAX
2330        ! JUST FOR VARIABLES USED
2340        !
2350        Luprms=Luprms(File2)
2360        IF Luprms=0 THEN 2450
2370          FOR I=1 TO Nscan2
2380            Rms=D2(I,Luprms)
2390            IF Rms<Rmsmaxallowed THEN 2440
2400            FOR Var=1 TO Npair
2410              Lup=Lup(File2,Var)
2420              D2(I,Lup)=Bad2
2430            NEXT Var
2440          NEXT I
2450        !
2460        IF Plotter$="NONE" THEN 2500
2470          PLOTTER IS Plotter$
2480          Xgdu=100*MAX(1,RATIO)
2490          Ygdu=100*MAX(1,1/RATIO)
2500        !
2510        FOR Pair=1 TO Npair
2520          Lup1=Lup(File1,Pair)
2530          Lup2=Lup(File2,Pair)
2540          !
2550          PRINT USING 2560;Set,File1no,File1$,Nvu1$(Lup1),File2no,File2$,Nvu2
$(Lup2)
2560          IMAGE /,"SET FILENO FILENAME          VARIABLE",/,3D,X,3D,4X,18A,18
A,/,4X,3D,4X,18A,18A
2570          !
2580          IF Process$<>"CROSSCOR" THEN 2620
2590            PRINT "DEPTH RANGE    AV1     AV2  R12MAX ZLAG   AVDIF  RMSDIF  O
K1  OK2   RMS1   RMS2"
2600            PRINT " (meters)                            (m)                  f
raction          "
2610            GOTO 2660
2620            !
2630          IF Process$<>"STRUCTURE" THEN 2660
2640            PRINT "DEPTH RANGE    AV1     AV2 ZLAG   AVDIF  RMSDIF  RMSMIN  O
K1  OK2   RMS1   RMS2"
2650            PRINT " (meters)                    (m)                          f
raction          "
2660            !
2670          IF (Process$<>"STRUCTURE") AND (Process$<>"CROSSCOR") THEN 3770
```

```
2680         !
2690         FOR Pie=1 TO Npie
2700           Zp1=Z1+(Pie-1)*Zpp
2710           Zp2=Zp1+Zpp
2720           !                          INTERPOLATE D1(*),D2(*) INTO Y1(*),Y2(*)
2730           DISP "INTERPOLATING"
2740           CALL Interp(D1(*),Nscan1,1,Lup1,Zp1,Dz,Npp,Bad1,Y1(*))
2750           CALL Interp(D2(*),Nscan2,1,Lup2,Zp1,Dz,Npp,Bad2,Y2(*))
2760           DISP ""
2770           !                    COMPUTE AVERAGES AND RMS PER PIECE
2780           S1=S2=0
2790           Ss1=Ss2=0
2800           Nok1=Nok2=0
2810           FOR I=1 TO Npp
2820             Y1=Y1(I)
2830             Y2=Y2(I)
2840             IF Y1=Bad1 THEN 2880
2850             Nok1=Nok1+1
2860             S1=S1+Y1
2870             Ss1=Ss1+Y1^2
2880             IF Y2=Bad2 THEN 2920
2890             Nok2=Nok2+1
2900             S2=S2+Y2
2910             Ss2=Ss2+Y2^2
2920           NEXT I
2930           Av1=Av2=0
2940           Std1=Std2=0
2950           IF Nok1 THEN Av1=S1/Nok1
2960           IF Nok1 THEN Std1=SQR(Ss1/Nok1-Av1^2)
2970           IF Nok2 THEN Av2=S2/Nok2
2980           IF Nok2 THEN Std2=SQR(Ss2/Nok2-Av2^2)
2990           !                      FORCE Y1(*), Y2(*) TO ZERO MEAN PER PIECE
3000           FOR I=1 TO Npp
3010             IF Y1(I)<>Bad1 THEN Y1(I)=Y1(I)-Av1
3020             IF Y2(I)<>Bad2 THEN Y2(I)=Y2(I)-Av2
3030           NEXT I
3040           !
3050           DISP "PROCESSING ";Process$
3060           IF Process$="CROSSCOR" THEN CALL Crosscor(Y1(*),Y2(*),Npp,-Nlagma
x,Nlagmax,R12(*),S11,S22,Bad1,Bad2,Ok1,Ok2)
3070           IF Process$="STRUCTURE" THEN CALL Structure(Y1(*),Y2(*),Npp,-Nlag
max,Nlagmax,R12(*),Bad1,Bad2,Ok1,Ok2)
3080           DISP ""
3090           !
3100           IF Process$<>"CROSSCOR" THEN 3210
3110           !      CROSS CORRELATION: FIND LAG WITH MAX CORRELATION
3120           R12max=-1
3130           FOR Lag=-Nlagmax TO Nlagmax
3140             IF R12max>R12(Lag) THEN 3170
3150             R12max=R12(Lag)
3160             Mlag=Lag
3170           NEXT Lag
3180           Zlag=0
3190           IF R12max<>0 THEN Zlag=Mlag*Dz
3200           !
3210           IF Process$<>"STRUCTURE" THEN 3320
3220           !      STRUCTURE FUNCTION: FIND LAG WITH RMS MINIMUM
```

```
3230          Rmsmin=R12(0)
3240          Mlag=0
3250          FOR Lag=-Nlagmax TO Nlagmax
3260            IF Rmsmin<R12(Lag) THEN 3290
3270            Rmsmin=R12(Lag)
3280            Mlag=Lag
3290          NEXT Lag
3300          Zlag=0
3310          IF Rmsmin>0 THEN Zlag=Mlag*Dz
3320          !
3330          Nd=Sd=Sdd=0                ! GET AVG AND RMS OF DIFFERENCE AT MLAG
3340          FOR I=MAX(1,1-Mlag) TO MIN(Npp,Npp-Mlag)
3350            Y1=Y1(I)
3360            Y2=Y2(I+Mlag)
3370            IF (Y1=Bad1) OR (Y2=Bad2) THEN 3420
3380            Dif=Y1-Y2
3390            Nd=Nd+1
3400            Sd=Sd+Dif
3410            Sdd=Sdd+Dif^2
3420          NEXT I
3430          !
3440          Avdif=Rmsdif=0
3450          IF Nd=0 THEN 3480
3460          Avdif=Sd/Nd
3470          Rmsdif=SQR(Sdd/Nd-Avdif^2)
3480          !
3490          IF Process$<>"CROSSCOR" THEN 3530
3500          !                                    PRINT FOR CROSS CORRELATION
3510          PRINT USING 3520;Zp1,Zp2,Av1;Av2;R12max;Zlag;Avdif;Rmsdif,Ok1,Ok2
,Std1,Std2
3520          IMAGE 2(5D),2(5D.DD),4D.3D,5D,2(5D.DD),2(2D.2D),2(5D.D)
3530          !
3540          IF Process$<>"STRUCTURE" THEN 3580
3550          !                                    PRINT FOR STRUCTURE FUNCTION
3560          PRINT USING 3570;Zp1,Zp2,Av1,Av2,Zlag,Avdif,Rmsdif,Rmsmin,Ok1,Ok2
,Std1,Std2
3570          IMAGE 2(5D),2(5D.2D),5D,3(5D.2D),2(2D.2D),2(5D.D)
3580          !
3590          IF Plotter$="NONE" THEN 3760
3600          IF Plotter$="GRAPHICS" THEN GRAPHICS
3610          !
3620          Xbox=Xgdu/Npair
3630          Ybox=Ygdu/Npie
3640          !
3650          LOCATE Xbox*(Pair-1),Xbox*Pair,Ybox*(Npie-Pie),Ybox*(Npie-Pie+1)
3660          FRAME
3670          IF Process$="CROSSCOR" THEN SCALE -Nlagmax,Nlagmax,-1,1
3680          IF Process$="STRUCTURE" THEN SCALE -Nlagmax,Nlagmax,0,5
3690          !
3700          P=-2
3710          FOR Lag=-Nlagmax TO Nlagmax
3720            PLOT Lag,R12(Lag),P
3730            P=-1
3740          NEXT Lag
3750          IF Plotter$="9872A" THEN PENUP
3760        NEXT Pie
3770        !
```

```
3780          IF Process$<>"COHERANCE" THEN 3880
3790          Nppp=Npp*Npie
3800          REDIM Y1(Nppp),Y2(Nppp)
3810          DISP "INTERPOLATING"
3820          Lup1=Lup(File1,Pair)
3830          Lup2=Lup(File2,Pair)
3840          CALL Interp(D1(*),Nscan1,1,Lup1,Z1,Dz,Nppp,Bad1,Y1(*))
3850          CALL Interp(D2(*),Nscan2,1,Lup2,Z1,Dz,Nppp,Bad2,Y2(*))
3860          !
3870          CALL Coher(Y1(*),Y2(*),Nppp,Nfft,Nband,Idif,Dz,Nvu1$(Lup1),Nvu2$(Lu
p2))
3880          !
3890        NEXT Pair
3900        !
3910        IF Plotter$<>"GRAPHICS" THEN 4050
3920        !                                   GRAPHICS
3930        PRINT PAGE
3940        PRINT "PROGRAM=";Progrev$,"RUN DATE&TIME";Runtime$
3950        PRINT "PROCESS$=";Process$
3960        IF Printer<>0 THEN 4000
3970          DUMP GRAPHICS
3980          PRINT PAGE
3990        !
4000          EXIT GRAPHICS
4010          GCLEAR
4020        !
4030        IF Plotter$<>"9872A" THEN 4060
4040        !                                    9872A
4050          PEN 0
4060        !
4070      NEXT File2
4080    NEXT File1
4090 NEXT Set
4100 !
4110  DISP "FINISHED"
4120  STOP
4130  !
4140  ! ************************************************************
4150  SUB Junk
4160  SUBEND
4170  ! **********************************************************
4180  SUB Crosscor(X(*),Y(*),N,L1,L2,Rxy(*),Sxx,Syy,Badx,Bady,Okx,Oky)
4190  Sxx=Syy=Nokx=Noky=0
4200  FOR I=1 TO N
4210    X=X(I)
4220    IF X=Badx THEN 4250
4230    Nokx=Nokx+1
4240    Sxx=Sxx+X^2
4250    Y=Y(I)
4260    IF Y=Bady THEN 4290
4270    Noky=Noky+1
4280    Syy=Syy+Y^2
4290  NEXT I
4300  Okx=Nokx/N
4310  Oky=Noky/N
4320  !
4330  MAT Rxy=ZER
```

```
4340 IF (Sxx=0) OR (Syy=0) THEN SUBEXIT
4350 !
4360 FOR L=L1 TO L2
4370   Sxy=0
4380   FOR I=MAX(1,1-L) TO MIN(N,N-L)
4390     J=I+L
4400     X=X(I)
4410     IF X=Badx THEN 4460
4420     Y=Y(J)
4430     IF Y=Bady THEN 4460
4440     Sxy=Sxy+X*Y
4450     Nokxy=Nokxy+1
4460   NEXT I
4470   Rxy(L)=Sxy/SQR(Sxx*Syy)
4480 NEXT L
4490 SUBEND
4500 ! ************************************************************
4510 SUB Junk
4520 SUBEND
4530 ! **************************************************************
4540 SUB Structure(X(*),Y(*),N,L1,L2,Rmslag(*),Badx,Bady,Okx,Oky)
4550 Nokx=Noky=0
4560 FOR I=1 TO N
4570   IF X(I)<>Badx THEN Nokx=Nokx+1
4580   IF Y(I)<>Bady THEN Noky=Noky+1
4590 NEXT I
4600 Okx=Nokx/N
4610 Oky=Noky/N
4620 !
4630 FOR Lag=L1 TO L2
4640   Nd=Sd=Sdd=0
4650    FOR I=MAX(1,1-Lag) TO MIN(N,N-Lag)
4660      X=X(I)
4670      Y=Y(I+Lag)
4680      IF (X=Badx) OR (Y=Bady) THEN 4730
4690      Nd=Nd+1
4700      Dif=X-Y
4710      Sd=Sd+Dif
4720      Sdd=Sdd+Dif^2
4730    NEXT I
4740   Av=Rms=0
4750   IF Nd=0 THEN 4780
4760   Av=Sd/Nd
4770   Rms=SQR(Sdd/Nd-Av^2)
4780   Rmslag(Lag)=Rms
4790 NEXT Lag
4800 SUBEND
4810 END
4820 ! *******************************************************
4830  SUB Interp(SHORT Din(*),REAL Nin,Zvar,Dvar,Z1,Dz,Nout,Bad,Dout(*))
4840  ! JUL 8,80 JHD. MODIFIED TO WORK WITH 2 DIM ARRAY INPUT, 1 DIM OUT
4850  OPTION BASE 1
4860  Dp=ABS(Dz)
4870  P1=ABS(Z1)
4880  MAT Dout=(Bad)
4890  J=2
4900  FOR Iout=1 TO Nout
```

```
4910     Pout=P1+(Iout-1)*Dp
4920     FOR J=J TO Nin            ! FIND PIN(J) JUST GREATER THAN POUT
4930       Pj=ABS(Din(J,Zvar))
4940       Dj=Din(J,Dvar)
4950       IF (Pj>=Pout) AND (Dj<>Bad) THEN 4980
4960     NEXT J
4970     SUBEXIT
4980         IF Pj<>Pout THEN 5010 ! SPECIAL SPEED-UP IF PJ=POUT
4990         Dout(Iout)=Dj
5000         GOTO 5070
5010     I=J-1                     ! INTERPOLATE LINEARLY IF Pi<POUT
5020     Pi=ABS(Din(I,Zvar))
5030     Di=Din(I,Dvar)
5040     IF Pi>Pout THEN 5070
5050     IF Di=Bad THEN 5070
5060     Dout(Iout)=(Dj-Di)/(Pj-Pi)*(Pout-Pi)+Di
5070   NEXT Iout
5080   SUBEND
5090   !
5100   ! ****************************************************************
5110   !
5120 SUB Coher(X(*),Y(*),Nin,Nfft,Nband,Idif,Delz,Labx$,Laby$)
5130   OPTION BASE 1
5140   SHORT Xx(Nfft),Yy(Nfft)
5150   Deg=180/PI
5160   Rad=1/Deg
5170   Delz=ABS(Delz)
5180   Npie=Nin DIV Nfft
5190   Nh=Nfft/2
5200   Dof=Nband*Npie
5210   IF Dof>1 THEN 5240
5220   DISP "DEGREES OF FREEDOM TOO SMALL"
5230   GOTO 5260
5240   T95=1.96+2.38/Dof+2.64/Dof^2+2.56/Dof^3
5250   C95=SQR(1-(1-.95)^(1/(Dof-1)))
5260   !
5270   PRINT "COHERANCE BETWEEN ";Labx$;" AND ";Laby$
5280   PRINT "NIN=";Nin,"NFFT=";Nfft,"NBAND=";Nband
5290   PRINT "NPIE=";Npie,"C95=";C95,"DOF";Dof
5300   PRINT " 1 EST 2  WNO   WLEN   AXX        AYY        CXY        QXY        RXY
 PXY  DPH"
5310   IMAGE 2(3D),5D.D,4D.2D,4(X,MD.2DE),2D.2D,2(5D)
5320   IF Idif=0 THEN S7
5330     FOR I=1 TO Nin-1
5340       X(I)=X(I+1)-X(I)
5350       Y(I)=Y(I+1)-Y(I)
5360     NEXT I
5370     X(Nin)=X(Nin-1)
5380     Y(Nin)=Y(Nin-1)
5390 S7:                          ! FFT
5400   FOR L=1 TO Npie
5410     L0=(L-1)*Nfft
5420     FOR I=1 TO Nfft
5430       Xx(I)=X(L0+I)
5440       Yy(I)=Y(L0+I)
5450     NEXT I
5460 !
```

```
5470      CALL Fork(Xx(*),Yy(*),Nfft,1)
5480 !
5490      Sc=SQR(2)/Nfft
5500      FOR I=1 TO Nfft
5510        X(L0+I)=Xx(I)*Sc
5520        Y(L0+I)=Yy(I)*Sc
5530      NEXT I
5540    NEXT L
5550 !
5560 FOR V=0 TO 4
5570    Kk=0
5580    FOR K=1 TO Nh-1 STEP Nband
5590      Axx=Ayy=Cxy=Qxy=Nav=0
5600      FOR L=1 TO Npie
5610        Ll=(L-1)*Nfft+1
5620        Ii=Ll+K
5630        Jj=Ll+Nfft-K
5640        FOR M=0 TO MIN(Nband,Nh-K)-1
5650          I=Ii+M
5660          J=Jj-M
5670          Xc=X(I)+X(J)
5680          Xs=Y(I)-Y(J)
5690          Yc=Y(I)+Y(J)
5700          Ys=X(J)-X(I)
5710          Cxy=Cxy+.5*(Xc*Yc+Xs*Ys)
5720          Qxy=Qxy+.5*(Yc*Xs-Xc*Ys)
5730          Axx=Axx+.5*(Xc^2+Xs^2)
5740          Ayy=Ayy+.5*(Yc^2+Ys^2)
5750          Nav=Nav+1
5760        NEXT M
5770      NEXT L
5780  !
5790      IF Idif<>1 THEN S22
5800      Recolor=4*SIN(PI*(K+.5*(Nband-1))/Nfft)^2
5810      Cxy=Cxy/Recolor
5820      Qxy=Qxy/Recolor
5830      Axx=Axx/Recolor
5840      Ayy=Ayy/Recolor
5850  !
5860 S22:  Kk=Kk+1
5870      Axx=Axx/Nav
5880      Ayy=Ayy/Nav
5890      Cxy=Cxy/Nav
5900      Qxy=Qxy/Nav
5910      Rxy=SQR((Cxy^2+Qxy^2)/(Axx*Ayy))
5920      Pxy=FNAtan(Qxy,Cxy)*Deg
5930  !
5940      Est1=(Kk-1)*Nband+1
5950      Est2=Kk*Nband
5960      Est=(Est1+Est2)/2
5970      Dph=T95*SQR((1/Rxy^2-1)/Dof)
5980      IF Dph>=1 THEN Dph=90
5990      IF Dph<1 THEN Dph=ASN(Dph)*Deg
6000      Wno=Est/Nfft/Delz*1E3
6010      Wlen=1E3/Wno
6020 !
6030      IF V>0 THEN 6190
```

```
6040     PRINT USING 5310;Est1,Est2,Wno,Wlen,Axx,Ayy,Cxy,Qxy,Rxy,Pxy,Dph
6050 !
6060     IF Kk>1 THEN 6110
6070     Axxmax=Axxmin=Axx
6080     Ayymax=Ayymin=Ayy
6090     Wnomax=Wnomin=Wno
6100 !
6110     Axxmax=MAX(Axxmax,Axx)
6120     Ayymax=MAX(Ayymax,Ayy)
6130     Axxmin=MIN(Axxmin,Axx)
6140     Ayymin=MIN(Ayymin,Ayy)
6150     Wnomax=MAX(Wnomax,Wno)
6160     Wnomin=MIN(Wnomin,Wno)
6170 !
6180     GOTO 6860
6190 !
6200     ON V GOTO Autoxx,Autoyy,Coher,Phase
6210 !
6220 Autoxx: !
6230     A=Axx
6240     IF Kk>1 THEN 6300
6250     PLOTTER IS "GRAPHICS"
6260     GRAPHICS
6270     LOCATE 0,50,50,100
6280     Lgtamin=LGT(Axxmin)
6290     Lgtamax=LGT(Axxmax)
6300     GOTO 6380
6310 !
6320 Autoyy: !
6330     A=Ayy
6340     IF Kk>1 THEN 6380
6350     LOCATE 0,50,0,50
6360     Lgtamin=LGT(Ayymin)
6370     Lgtamax=LGT(Ayymax)
6380   !
6390     IF Kk>1 THEN 6550
6400     Lgtwmin=LGT(Wnomin)
6410     Lgtwmax=LGT(Wnomax)
6420     Ilgtwmin=INT(Lgtwmin)
6430     Ilgtwmax=INT(Lgtwmax+.999)
6440   !
6450     Ilgtamin=INT(Lgtamin)
6460     Ilgtamax=INT(Lgtamax+.999)
6470   !
6480     SCALE Ilgtwmin,Ilgtwmax,Ilgtamin,Ilgtamax
6490     LINE TYPE 3,1
6500     GRID 1,1
6510     LINE TYPE 1
6520     FRAME
6530     MOVE LGT(Wno),LGT(A)
6540     GOTO 6860
6550 !
6560     DRAW LGT(Wno),LGT(A)
6570     GOTO 6860
6580 !
6590 Coher:    !
6600 !
```

```
6610      IF Kk>1 THEN 6690
6620      LOCATE 50,100,0,50
6630      SCALE Ilgtwmin,Ilgtwmax,0,1
6640      LINE TYPE 3,1
6650      GRID 1,.2
6660      LINE TYPE 1
6670      FRAME
6680      MOVE LGT(Wno),Rxy
6690 !
6700      DRAW LGT(Wno),Rxy
6710      GOTO 6860
6720 !
6730 Phase: !
6740 !
6750      IF Kk>1 THEN 6830
6760      LOCATE 50,100,50,100
6770      SCALE Ilgtwmin,Ilgtwmax,-180,180
6780      LINE TYPE 3,1
6790      GRID 1,90
6800      LINE TYPE 1
6810      FRAME
6820      MOVE LGT(Wno),Pxy
6830 !
6840      DRAW LGT(Wno),Pxy
6850 !
6860   NEXT K
6870 NEXT V
6880 !
6890   DUMP GRAPHICS
6900   PRINT PAGE
6910   EXIT GRAPHICS
6920 SUBEND
6930  !
6940 ! ***********************************************************************
6950  !
6960 SUB Fork(SHORT X(*),Y(*),REAL Lx,Signi) ! MODIFIED FROM DENHAM'S PATSY FFT
6970   J=1
6980   FOR I=1 TO Lx                  ! SORT IN TIME DOMAIN
6990     IF I>J THEN S10
7000     Rtemp=X(J)
7010     Itemp=Y(J)
7020     X(J)=X(I)
7030     Y(J)=Y(I)
7040     X(I)=Rtemp
7050     Y(I)=Itemp
7060 S10: M=Lx/2
7070 S20: IF J<=M THEN S30
7080     J=J-M
7090     M=M/2
7100     IF M>=1 THEN S20
7110 S30:    J=J+M
7120   NEXT I
7130   L=1
7140 S40:    Istep=2*L            ! FOLD IN FREQ DOMAIN
7150   FOR M=1 TO L
7160     Iarg=PI*Signi*(M-1)/L
7170     Rw=COS(Iarg)
```

```
7180     Iw=SIN(Iarg)
7190     FOR I=M TO Lx STEP Istep
7200       Ipl=I+L
7210       Rtemp=Rw*X(Ipl)-Iw*Y(Ipl)
7220       Itemp=Rw*Y(Ipl)+Iw*X(Ipl)
7230       X(Ipl)=X(I)-Rtemp
7240       Y(Ipl)=Y(I)-Itemp
7250       X(I)=X(I)+Rtemp
7260       Y(I)=Y(I)+Itemp
7270     NEXT I
7280   NEXT M
7290   L=Istep
7300   IF L<Lx THEN S40
7310 SUBEND
7320 ! ******************************************************************
7330 DEF FNAtan(Y,X)
7340   IF X=0 THEN Vert
7350   Ang=ATN(Y/X)
7360   IF X>0 THEN RETURN Ang
7370   IF Y<0 THEN Q3
7380   Ang=Ang+PI
7390   RETURN Ang
7400 Q3:   Ang=Ang-PI
7410   RETURN Ang
7420 Vert:   IF Y<0 THEN Down
7430   Ang=PI/2
7440   RETURN Ang
7450 Down:   Ang=-PI/2
7460 FNEND
7470 ! **************************************************************
7480 END
```

APPENDIX B
Flotation and Fuse Assembly

I. Materials

- A. Knife
- B. Velux 10 lb nylon monofilament fishing leader
- C. Rubber bands, about 3" x 1/4"
- D. Orange wax safety fuse
- E. Flotation collars (Fig. B1)
- F. Pull-wire igniters and instructions

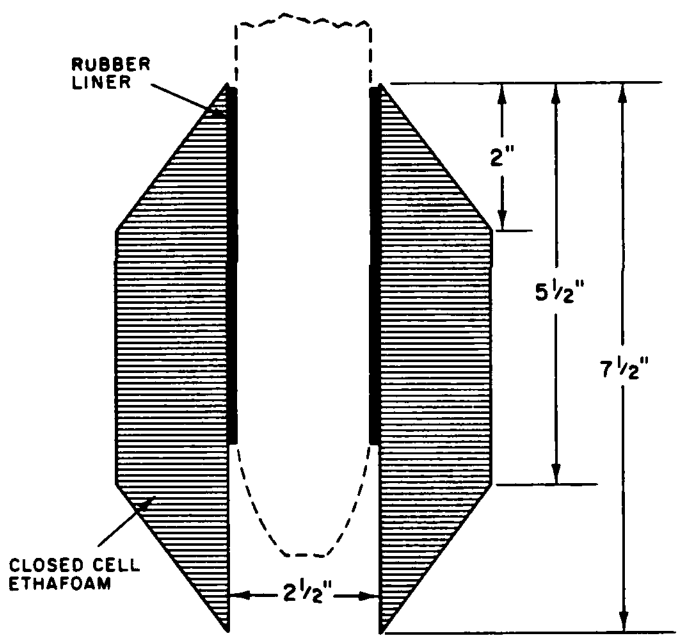


Figure B1. XTVP expendable float, side view cross section.

II. Assembly

- A. Loop two rubber bands together (Fig. B2).
- B. Thread an 8" piece of leader material through both rubber bands, and tie end with surgeon's knot (Fig. B2).

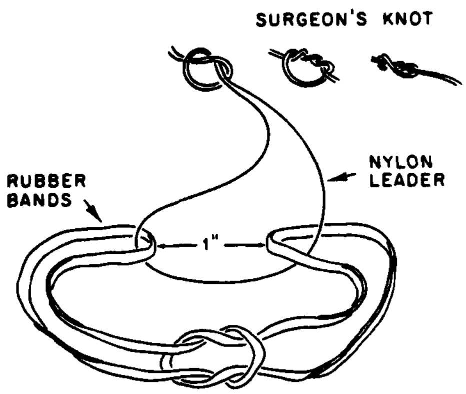


Figure B2.

Leader material threaded through looped rubber bands and tied in surgeon's knot.

C. Slip rubberband/line assembly over the foam float as shown in Fig. B3.

D. Prepare fuse by measuring amount needed for desired delay time (orange wax safety fuse burns at 120 sec/yard) plus 5", and cut ends square. Scrape ignitor end to expose powder for reliable ignition.

E. At the measured point, make a single straight cut in the safety fuse to 1/2 diameter so that knife cut extends into channel filled with fuse burning material, as shown in Fig. B3.

F. Use a pencil to punch hole into Ethafoam float in longitudnal line with fishline as shown in Fig. B3.

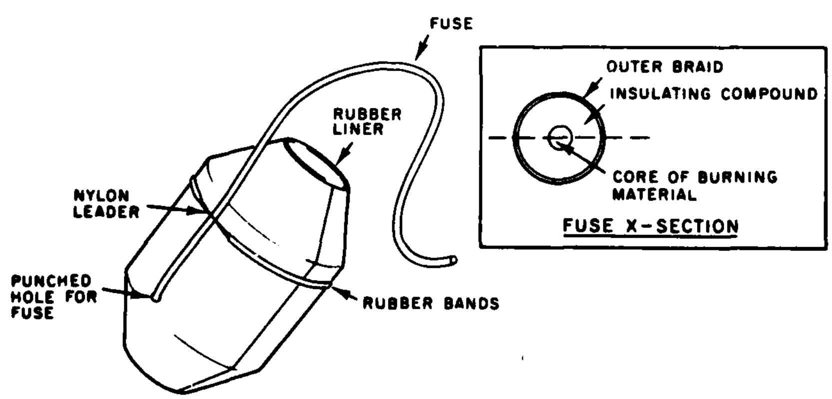


Figure B3. Foam float with rubber band assembly; fuse cut to half the diameter and attached with cut under nylon leader.

G. Insert fuse into float
   1. with end of fuse in hole of float
   2. with fishline inserted into cut in fuse so that when fuse burns down it will melt the nylon and release the float halves.

H. Install assembly in launcher and secure in place.

I. When ready to deploy, pull wire fuse igniter according to instructions on igniter box, being careful that igniter is pushed well down onto the fuse and that it is not pulled off when the wire is pulled.

J. The operator should test the method several times to ensure good technique. (Use XBT's to economize.)